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Trends in Kenyan Agricultural Productivity: 1997-2007

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ABSTRACT

Agriculture continues to be a fundamental instrument for sustainable development, poverty reduction and enhanced food security in developing countries. Agricultural productivity levels in Sub Sahara Africa are far below that of other regions in the world, and are well below that required to attain food security and poverty reduction goals. On the other hand, the *rate* of agricultural productivity growth since the early 2000s has been quite impressive in many African countries, including Kenya, yet this is no cause for complacency. Sustained and accelerated growth requires a sharp increase in productivity of smallholder farmers. The Strategy to Revitalize Agriculture (SRA), Kenya Vision 2030, Comprehensive African Agricultural Development Program (CAADP) and Alliance for Green Revolution in Africa (AGRA) have underscored the importance of increasing agricultural productivity in the fight against poverty. In the past, agricultural production was largely a function of acreage, but further growth in production will have to be driven by productivity growth.

The paper analyzes trends in the Kenyan agricultural productivity using nationwide household panel survey data collected from 1275 households in eight Agro-regional zones for 1996/1997, 1999/2000, 2003/2004 and 2006/2007 cropping years. This panel data analysis overcomes problems of comparability and differences in sample design that compromise other trend assessments and thus provides a unique opportunity to evaluate changes in smallholder agricultural productivity. Productivity changes for maize, tea, coffee, sugarcane, cabbages, Irish potatoes and dairy are examined. The major drivers of the productivity trends across the agro-regional zones are discussed. The paper identifies policy interventions required to either sustain productivity growth or improve declining and stagnating sub-sectors.

Results show a consistent growth in maize productivity across most agro-regional zones and panel years. Some of the key factors that have contributed to productivity growth in maize over the 1997-2007 period include increased percentage of smallholder households using fertilizer, more complete adoption of high-yielding seed varieties adoption, and an increased density of fertilizer retail outlets leading to a decline in the distances to sellers of agricultural inputs. Fertilizer use dose rates on maize, however, have remains fairly constant. Further analysis reveals that some households did not use inorganic fertilizers and the defining feature of these households is location in semi-arid areas where fertilizer use on maize may be risky and unprofitable.

The dairy sub-sector recorded impressive growth over the 1997-2007 period. Increased investment in dairy production and production of fodder crops reflects increased adoption of improved breeds, highlighting the importance of investment in knowledge and technology. Tea productivity has grown slightly, driven by increased fertilizer use, especially in the Western regions of Kisii and Vihiga districts. Productivity of sugarcane and coffee, on the contrary, declined during the decade, mainly due to challenges, some related to management, facing the sub sectors. Cabbage and Irish potato productivity fluctuated over the panel period, and did not show any meaningful trend.

The per capita land owned and per capita cultivated land has declined over the panel period, which appears to be related to intensifying population pressures and land fragmentation in many areas of the country. More than 30 percent of the smallholder farms in the sample control less than 1 acre of land. While agricultural productivity in general appears to be rising in Kenya, rising land pressures in the more densely populated areas is a major threat to future food security and rural livelihoods. Productivity growth and market access can partially overcome these threats, but sustainable rural livelihoods may well require attention to improved access to land.

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AEZ	-	Agro-ecological Zone
AGARA	-	Alliance for Green Revolution in Africa
ASPS	-	Agricultural Sector Program Support
CAADP	-	Comprehensive African Agricultural Development Program
CDF	-	Constituency Development Fund
GoK	-	Government of Kenya
HYV	-	High Yielding Variety
IFDC	-	International Fertilizer Development Center
KAPP	-	Kenya Agricultural Productivity Project
KNBS	-	Kenya National Bureau of Statistics
MSU	-	Michigan State University
NAAIAP	-	National Accelerated Agricultural Inputs Access Program
NALEP	-	National Agriculture and Livestock Extension Program
NGO	-	Non-governmental Organization
SRA	-	Strategy for Revitalizing Agriculture
SSA	-	Sub-Saharan Africa
TAMPA	-	Tegemeo Agricultural Monitoring and Policy Analysis Project
USAID	-	United States Agency for International Development
CoDF	-	Coffee Development Fund
KARI	-	Kenya Agricultural Research Institute

1. INTRODUCTION

1.1 Background

In the 21st century, agriculture continues to be a fundamental instrument for sustainable development, poverty reduction and enhanced food security in developing countries. Agricultural productivity growth is also vital for stimulating growth in other sectors of the economy. Currently, agricultural productivity growth in Sub Sahara Africa (SSA) lags behind that of other regions in the world, and is well below that required to achieve food security and poverty goals (World Bank, 2007).

The Strategy for Revitalizing Agriculture (SRA) has underscored the importance of increasing agricultural productivity in the fight against poverty (Republic of Kenya, 2004). The Strategy has decomposed the productivity problem into three components; an extension problem, a research problem and an economic and financing problem. The Kenya Vision 2030 has also highlighted growth of the agricultural sector as a major challenge (Republic of Kenya, 2007). Other important regional strategies such as the Comprehensive African Agricultural Development Program (CAADP) and the Alliance for Green Revolution in Africa (AGRA) have also underscored the need for productivity growth.

Over the past five years, the Kenyan Government has strived to improve agricultural productivity through government and donor supported programs such as Kenya Agricultural Productivity Project (KAPP), Agricultural Sector Programme Support (ASPS), National Agriculture and Livestock Extension Programme (NALEP), and the National Accelerated Agricultural Inputs Access Programme (NAAIAP). However, there is very little evidence-based documentation showing the impact of these programmes on smallholder farmers. This paper provides an assessment of the success of these programs in promoting agricultural productivity in Kenya over the past decade. The study, therefore, seeks to analyze productivity trends in major commodities with an overall objective of establishing if there are lessons that could be learnt from the past. These lessons could provide important guidance as the country strives to implement the Kenya Vision 2030.

1.2 Objectives

The overall objective of the paper is to analyze trends in the Kenyan agricultural productivity using nationwide household panel survey data. In particular, the paper examines productivity trends for selected cereal, industrial, and horticultural crops and dairy sub sectors. The paper identifies commodities that have recorded positive growth in productivity and highlights the major drivers of productivity growth across agro-regional zones. Sub-sectors with declining or stagnating productivity over the decade are also identified. The paper proposes some policy interventions required to sustain productivity growth for sub-sectors with positive growth and improve productivity for sub-sectors showing declining and stagnating trends.

It is envisaged that the study findings will inform stakeholders in the agricultural sector on levels of productivity over time, technology adoption or dis-adoption and the intensity of use of inputs. The study results will reinforce the need to expand support for innovative systems of input distribution such as agro-dealer programs and the proposed fertilizer cost reduction strategy as identified in the Kenya Vision 2030. Results could also provide evidence for the need for targeted interventions.

2 DATA AND METHODS

2.1 Data and Sampling

The data for the study is obtained from the Tegemeo/MSU panel Household Survey for 1996/97, 1999/00, 2003/04 and 2006/07 cropping years. The panel household survey was designed and implemented under the Tegemeo Agricultural Monitoring and Policy Analysis Project (TAMPA), implemented by Egerton University/Tegemeo Institute, with support from Michigan State University.

The sampling frame for the panel was prepared in consultation with the Kenya National Bureau of Statistics (KNBS) in 1997; although KNBS's agricultural sample frame was not made available. Twenty-four (24) districts were purposively chosen to represent the broad range of agro-ecological zones (AEZs) and agricultural production systems in Kenya. Next, all non-urban divisions in the selected districts were assigned to one or more AEZs based on agronomic information from secondary data. Third, proportional to population across AEZs, divisions were selected from each AEZ. Fourth, within each division, villages and households in that order were randomly selected. A total of 1,578 households were selected in the 24 districts within seven agriculturally-oriented provinces of the country. The sample excluded large farms with over 50 acres and two pastoral areas. This analysis is based on 1,275 households which formed a balanced panel for each of the four cropping years, 1996/1997, 1999/2000, 2003/04 and 2006/07 (hereafter referred to as 1997, 2000, 2004 and 2007, respectively). The attrition rate for the panel was 19% over the 10-year period. Some of the main reasons for this attrition are related to death of household heads and spouses leading to dissolution of households, and relocation of households from the study areas. Households in Turkana and Garissa districts were not interviewed in the 2004 and 2007 surveys. The 22 districts in the survey were assigned to agro-regional zones as defined in Table 1.

Table 1: Spread of sampled districts in agro-ecological zones

Agro-ecological zone	Districts
Coastal Lowlands	Kilifi, Kwale
Eastern Lowlands	Machakos, Mwingi, Makueni, Kitui, Taita-Taveta
Western Lowlands	Kisumu, Siaya
Western Transitional	Bungoma (lower elevation), Kakamega (lower elevation)
Western Highlands	Vihiga, Kisii
Central Highlands	Nyeri, Muranga, Meru
High-Potential Maize Zone	Kakamega (upper elevation), Bungoma (upper elevation) Trans Nzoia, Uasin Gishu, Bomet, Nakuru, Narok
Marginal Rain Shadow	Laikipia

A major advantage of panel data is that it overcomes problems of comparability over time. In many countries, there are various farm surveys to draw upon to measure trends in livelihoods and agricultural performance over time. However, the comparability of these surveys is often compromised by differences in sampled households, locations, month/season of interview, recall period, and the way in which data is collected. The findings reported in this study are based on a balanced panel of 1,275 households consistently interviewed in 1997, 2000, 2004, and 2007, which provides a unique opportunity to track changes in agricultural performance for a consistently defined nationwide sample of small-scale farmers. Another advantage of panel data is that it allows sorting out economic effects that cannot be distinguished with the use of either cross-section or aggregate time-series data alone (Pindyick and Rubinfeld, 1998). Incorporating information containing cross-section and time-series dimensions can substantially diminish the problems that arise when there is an omitted-variables problem (Hsiao, 1986) which is otherwise present in Ordinary Least Square procedure. Other studies that have used panel data to measure productivity include Ekborm (1998), Yamano and Jayne (2004), Suri (2006) and Tegemeo (2005). The present study, however, relies on in-depth and longer panel period (10 years).

2.2 Method of Analysis

The aim of this paper is to provide a fundamental picture of trends in agricultural productivity and hence relies largely on descriptive trends. Descriptive analysis is used to show trends in partial productivity measures such as crop output per unit of land and labor. The paper also examines trends in input use over the panel period. Values over time are expressed in constant terms using mean farm-gate output prices over the four panel survey periods. This procedure enables us to track changes over time in farm output based on changes in physical production per unit of land and labor and effectively purges out the effects of price variations caused largely by exogenous shocks to the sector. We also use econometric techniques to identify the major determinants of maize productivity growth on smallholder farms after controlling for other factors, and to examine the significance of the various productivity determinants. To achieve this aim, we estimate Cobb Douglas production function for maize. We focus on maize because it is a strategic food staple in Kenya, occupying over 50% of cropped land, and is produced by virtually all households in this survey.

The Cobb-Douglas production function is widely used for productivity analysis due to its relative simplicity and convenience in specification and interpretation. The function is specified as follows:

$$y_{it} = bx_{it} + \varepsilon_{it},$$

where y is the dependent variable (in this case productivity), x is a vector of inputs (such as high yielding varieties, fertilizer, labor), demographic characteristics (such as education, gender, age) and access to markets (such as road distance), b is a vector of parameters to be estimated, i and t are indices for individual households and time, respectively, and ε_{it} is the error term. All the variables are in log form (i.e. the Cobb-Douglas Production Function has been made linear by taking its log). We estimate fixed effects models to control for unobserved time-invariant effects, which would otherwise contribute to parameter bias. In this way, the use of household panel data can provide a more accurate indication of the factors driving smallholder productivity growth and thereby provide more meaningful guidance to policy makers.

3 AGRICULTURAL PRODUCTIVITY TRENDS

This section presents trends in aspects of agricultural productivity. Trends in household land ownership and cultivation are presented in Section 3.1. Section 3.2 presents household income composition and explains the relative importance of various income sources in household total income. Trends in value of crop production are presented in Section 3.3. Productivity trends for selected commodities and drivers of the observed trends are presented in Section 3.4.

3.1 Land ownership

Household land holdings have generally declined from 6.1 acres in 1997 to 5.8 acres in 2007 (Table 2). This decline was experienced in five out of the eight agro-regional zones, with marginal rain shadow registering the highest decline of 15% from 6.1 acres in 1997 to 4.4 acres in 2007. Western highlands, however, shows a slight increase in mean household land sizes from 2.2 to 2.4 acres during the panel period. The general decline in sizes of landholding reflects the effects of increased population pressures and sub-division in most areas of rural Kenya. The trends also show regional differences in the size of household land holdings, with households in the High potential maize zone owning an average of 10 acres. Households in the Western highlands and Central highlands have the smallest land holdings (between 2 and 3 acres).

Table 2: Trends in mean land size owned (acres[1]/household)

Zone	1997	2004	2007
Coastal Lowlands	5.3	6.3	5.3
Eastern Lowlands	6.7	5.6	6.4
Western Lowlands	3.8	4.2	3.0
Western Transitional	5.9	6.3	5.8
High Potential Maize Zone	10.7	11.0	10.4
Western Highlands	2.2	2.3	2.4
Central Highlands	2.9	2.9	3.0
Marginal Rain Shadow	6.1	5.1	4.4
Overall Sample	**6.1**	**6.1**	**5.8**

The average cropped land per household has declined from 3.5 acres in 1997 to 3.4 acres in 2007 (Table 3). The declining trend in cropped area is also observed in all the regions except Eastern lowlands, where the average area rose from 3.1 to 4.0 acres between 1997 and 2007. The expansion in area in the Eastern lowlands may reflect less intense land pressures in this less densely populated zone and continued reliance on land extensification.

[1] 1 acre=0.4 hectares

Table 3: Mean area cultivated for main season (acres per household), 1997- 2007

Zone	1997	2004	2007
Coastal Lowlands	2.8	4.0	3.3
Eastern Lowlands	3.1	4.4	4.0
Western Lowlands	2.3	3.2	2.3
Western Transitional	4.3	4.2	4.1
High Potential Maize Zone	5.9	5.1	5.1
Western Highlands	1.7	2.1	2.0
Central Highlands	2.2	2.5	2.0
Marginal Rain Shadow	1.9	1.9	1.8
Overall Sample	**3.5**	**3.7**	**3.4**

We further analyse mean cropped land for selected crops. Results show that area under maize production increased from 1.8 acres in 1997 to 2.2 acres in 2000**,** before declining to 1.9 acres in 2004 and 2007 (Table 3). The proportion of households producing maize has remained high and somewhat constant; averaging 99%. This indicates the importance attached to maize by most rural households in Kenya.

Area under tea declined marginally from 1.08 acres in 1997 to 1.05 acres in 2007, but the number of tea growing households in the sample rose from 170 to 194 during the decade, with the net result being a moderate increase in tea production over the full sample. This could be a response to liberalization and privatization of tea, which entailed the exit of the government from tea production, revocation of the tea license, and transformation of the Kenya Tea Development Authority to Kenya Tea Development Agency, the latter being owned by the farmers.

The area under coffee production declined from 0.56 acres in 1997 to 0.48 acres in 2007. The number of coffee growing households in the sample also fell from 257 in 1997 to 250 in 2007, with the net result being a decline in coffee output over the entire sample. This finding is not surprising given the management difficulties that the sector has suffered over the past decade and beyond (Nyoro and Ngugi, 2006).

The area under sugarcane during the period rose from 2.18 acres in 1997 to 2.5 acres in 2007, but the number of households in the sample producing sugar cane declined from161 to 145 between 1997 and 2007, with the net result being a moderate rise in aggregate production over the decade.

Cabbages, a major horticultural crop in Kenya, show a decline in the area cultivated from 0.38 acres in 1997 to 0.21 acres in 2007, although the total number of households engaged in cabbage production rose greatly from 1997 to the early 2000s, before declining in 2007. The number of farmers growing Irish potatoes similarly rose dramatically in the late 1990s and early 2000s before declining somewhat between 2004 and 2007. Overall, the percentage of farmers growing potatoes has increased from roughly 25% to 33%. Among farmers who planted potatoes, area cultivated has declined gradually, from 0.58 in 1997 to 0.44 acres in 2007. The declining trend in acreages under most of the crops indicate that land is increasingly becoming a constraining factor in agricultural production, and any increase in agricultural production will need to be attained only through productivity growth. This is consistent with the finding that a smaller share of land is under fallow in 2007 than in 1997.

Table 3: Mean land area under selected crops for household cultivating the crop, main season, 1997- 2007

Crop	Acres under cultivation for households cultivating the crop							
	1997		2000		2004		2007	
	No. of hhs	Area (acres/hh)	No. of hhs	Area (acres/hh)	No. of hhs	Area (acres/hh)	No. of hhs	Area (acres/hh)
Maize	1260	1.80	1259	2.20	1261	1.90	1254	1.90
Tea	170	1.08	177	1.04	198	1.01	194	1.05
Coffee	257	0.56	308	0.55	283	0.49	250	0.48
Sugarcane	161	2.18	154	2.18	158	2.03	145	2.50
Cabbages	134	0.38	286	0.24	217	0.21	168	0.21
Potatoes	327	0.58	486	0.59	490	0.48	413	0.44

Note: the full nationwide sample contains 1,275 households.

Table 4 provides trends in overall cropped land and proportion allocated to maize production. All the regions show a general declining trend in area under maize; except for Eastern lowlands in which maize area rose form 2.3 acres to 2.9 acres over the decade.

Over 50% of cropped land is allocated to maize, including both intercrop and monocrop fields, signifying the importance attached to maize production among the farmers. This proportion is, however, consistently declining during the panel period; from 59% in 1997 to 55% in 2007. Regionally, there is a marked consistent decline in the proportion of area under maize to total cropped area in Western highlands, Western lowlands and Central highlands. It is also observed that these are the regions where mean household landholding size is relatively small compared to other regions, and where other higher-valued crops and activities such as tea, horticulture, dairy and associated fodder crop production may provide higher returns to scarce land. The proportion of land under maize has risen between 1997-2007 in areas where land pressures are less acute and where landholding sizes are larger, such as the Coastal and Eastern lowlands, Western transitional and Marginal rain shadow regions.

Table 4: Trends in Cropped Land and Land Allocation to Maize, 1997-2007

[redacted]

3.2 Household Income Composition

Household income constitutes income from cropping activities, sale of livestock and livestock products, business activities, income from salaries income and remittance. Decomposition of household income into its components reveals that crop income is a major component of household income, contributing 40% in 1997, 50% in 2000, 46% in 2004 and 44% in 2007 (Table 5). Variations over time in agriculture income shares is highly weather-driven,

Regionally, crop incomes have remained an important contributor to household income in the Highlands, Western transitional and High potential maize zones, contributing between 41% and 65% over the decade. In the semi-arid areas such as Coastal and Eastern lowlands and Marginal rain shadow, crops generally contribute less to total household incomes – between 10% and 43% - compared to the high potential agricultural regions. In the Marginal rain shadow, however, crop's contribution to household income consistently rose from 13% in 1997, 23% in 2007, 33% in 2004, to 36% in 2007.

Table 5: Household Annual Income Shares (% of total household income), 1997-2007

Zone	Year	Crops	Livestock	Business	Salary
Coastal Lowlands	1997	10.3	5.3	38.7	45.7
	2000	39.1	3.1	37.1	20.7
	2004	24.1	4.0	42.2	29.7
	2007	28.8	1.9	48.8	20.5
Eastern Lowlands	1997	21.8	16.4	13.3	48.5
	2000	43.1	12.3	19.7	24.9
	2004	34.4	11.2	24.3	30.1
	2007	40.1	13.0	20.8	26.1
Western Lowlands	1997	41.0	17.7	13.0	28.3
	2000	50.3	15.0	17.1	17.6
	2004	37.4	12.9	23.6	26.2
	2007	39.8	7.4	30.1	22.7
Western Transitional	1997	47.1	24.4	13.6	15.0
	2000	61.9	10.4	16.1	11.6
	2004	56.2	14.8	15.3	13.7
	2007	47.7	16.7	23.2	12.4
High Potential Maize Zone	1997	48.6	24.3	9.6	17.5
	2000	40.6	24.5	18.6	16.3
	2004	50.6	20.7	12.8	15.9
	2007	38.3	25.8	19.7	16.3
Western Highlands	1997	45.5	21.8	10.7	22.0
	2000	58.8	14.7	8.0	18.5
	2004	49.2	17.7	10.8	22.3
	2007	54.8	11.5	15.6	18.1
Central Highlands	1997	43.9	19.4	9.7	27.0
	2000	64.7	8.6	11.7	15.0
	2004	53.2	17.3	11.5	18.0
	2007	54.7	15.8	13.2	16.3
Marginal Rain Shadow	1997	12.9	35.0	14.9	37.2
	2000	22.9	10.2	34.2	32.7
	2004	32.9	22.9	16.2	28.0
	2007	36.2	26.2	16.1	21.6
Overall Sample	1997	40.0	21.0	13.0	27.0
	2000	50.0	15.0	17.0	18.0
	2004	46.0	16.0	17.0	21.0
	2007	44.0	16.0	21.0	18.0

Income from livestock contributed 21% of household income in 1997, but the contribution declined to 16% in 2007. While the declining trend in livestock contribution to household income is mirrored across all the regions, in the Marginal rain shadow livestock contribution to household income shows a general increasing trend between 10 % in 2000 and 26% in 2007.

The proportion of income from business rose from 13% in 1997 to 21% in 2007. The increase in the proportion of business income to total household income over the decade is also observed in all the regions. The largest increases were in the Western lowlands (from 13% in 1997 to 30% in 2007), Coastal lowlands (from 39% in 1997 to 49% in 2007) and the High potential maize zone (from 10% in 1997 to 20% in 2007). The contribution of salaries and remittances show a declining trend for all the zones from 27% in 1997 to 18% in 2007.

Jointly, the contribution from on-farm income earning activities (crops and livestock income) declined gradually but consistently from 65% in 2000 to 60% and 2007. The proportion of off-farm income (business and salary incomes combined) increased from 35% in 2000 to 38% in 2000 to 40% in 2007. This shows the increasing importance of off-farm activities to rural agricultural households. However, farming is still a major source of household income among the rural households. Agricultural productivity growth, therefore, remains a major target in efforts to improve incomes and well-being of the majority of the rural households.

3.3 Value of Crop Production

The value of crop production is defined as the product of the quantity of crop harvested and the price for all the crops produced by the household. Since the value of crop production changes with the change in either price or quantity, we use constant prices[2] to evaluate the changes in order to determine whether the changes are as a result of changes in quantities of production. Holding prices of all commodities constant, we observe a general increase in the value of crop production over the decade across all the zones (Table 6). Overall, the mean value of crop production per household at constant prices rose from Ksh 62,000 in 1997 to Ksh. 72,264 in 2007. However, the values were higher in 2000 and 2004. A similar trend is observed in the value of crop production per acre which rose from Ksh. 16,005 in 1997 to Ksh. 19,869 in 2007. Central highland has the highest mean value of crop production per acre, ranging from Ksh. 30,808 in 1997 to Ksh. 40,200 in 2007. The High potential maize zone recorded the second highest value of crop production per acre; the value increased from Ksh 16,000 in 1997 to Ksh, 19,241 in 2007. Western highlands also recorded an increase in mean crop value per acre from

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2

Crop value at time t is computed as

$$V_t = \sum_{i=1}^{n} \left\{ Q_{it} \times \left[\left(\sum_{t=1}^{4} P_{it}^{dm} \right) / 4 \right] \right\}$$

V_t = Gross crop value at time t

Q_i = Quantity in kilograms of crop i at time t

P_{it}^{dm} = Median district price per kilogram of crop i at time t

t=year, 1=1997, 2=2000, 3=2004, 4=2007

Ksh. 11,325 in 1997 to Ksh. 17,662 in 2007. Western transitional had the fourth largest crop value per acre of Ksh. 12,317 in 1997 to Ksh 15,504 in 2007. The lowest value of crop produced per acre was recorded in the Eastern lowlands, Western lowlands, Coastal lowlands and the Marginal rain shadow. These trends imply that the main source of increase in the value of crop production is yield growth and shifts from low-value to high-value crops, as area under cultivation has declined somewhat over the panel period.

Table 6: Mean Total Value of Crop production at Constant Price, 1997-2007

[redacted]

Although the data has shown a general increase in the value of crop production during the panel period, there is still a gender disparity in the value of crop between the female and male-headed households. The female-headed households generally recorded lower values of crop production than their male-headed counterparts (Annex 1). It is noted that female-headed households in the higher productive zones had higher crop values than their counterparts in the lower productive zones. Over the panel period, the proportion of female- headed households doubled from 11.9% to 23.5%, mainly as a result of death[3] of male heads and male migration off the farm in search on non-farm jobs.

3.3.1 Contribution of selected crops to the Total Crop Value

The total value of crop constitutes revenue from cereals, tubers, pulses, fruits and vegetables, industrial crops and fodder. On the overall, maize contributed 36% of the total value of crop in 1997, before declining to 29% (Table 7). This proportion rose to 34% in 2007. Regionally, the contribution of maize to total crop value in the High potential maize zone declined from 52% in1997 to 48% in 2000 and 2004 and later rose to 51% in 2007. A similar trend has been observed across the other agro-regional zones, where the proportion of maize value in total crop value declined in 2000 and then took an upward trend between 2004 and 2007. In the Central highlands, the proportion of maize value to total crop value has remained low, declining from 14% in 1997 to 11% in 2004, and then rising to 12% in 2004 and 2007.

The importance of other crops in contributing to value of crop varies across regions. In the Coastal lowlands, vegetables and fruits contributes over 40% of the crop value. Over the panel years, there was a steady increase of contribution of pulses from 9% to 14%. This could be attributed to increased promotion of drought resistant crops in the region. In the Eastern lowlands, pulses, vegetables and fruits contribute over 50% of the total crop value, but during the panel period there was a marked increase in the proportion of crop revenue generated from fodder crops. In the Western lowlands, other cereals such as millet and sorghum contributed over 20% of the total value of crop. Over the panel period we observe a substantial increase in the proportion of crop revenue generated from fruits (2% in 1997 to 13% in 2007) and vegetables (1% in 1997 to 14% in 2007).

In Western transitional zone, over 25% of the crop revenue is generated from industrial crops; mainly sugarcane. During the panel period we observed an increase in proportion of revenue generated by a combination of fruits and vegetables (from 17% in 1997 to 20% in 2007). In the High potential maize zone, other cereals such as wheat contributed over 10% of the crop value. However, during the years under examination, we observe an increase in the importance of fruits and vegetables (from 7% in 1997 to 14% in 2007) in the region. In addition, fodder contributed 5% of the crop value in 2007 compared to 1% in 2000. In the Central highlands, industrial crops (e.g. tea and coffee) contribute the highest proportion (over 32%). There were, however, wide fluctuations in this proportion over the decade, which could be associated with challenges in the coffee sub-sector. An increasing trend in the contribution of fodder to total crop revenue is observed for the region; from 6% in 2000 to 8% in 2007.

Overall, we observe an increasing importance of contribution of fodder crop (related to dairy) and horticulture to value of crop production during the panel period.

[3] Further analysis of the mortality revealed that most of the household heads that died were male and the main causes of death were cancer (14.9%) and asthma (10.4%) between 2000-2004, and malaria and old age (each 10.9%) and accident (9.4%) between 2004-2007

Table 7: Percent Contribution Various Crops to Total Crop Gross Production Revenue, 1997-2007.

[redacted]

3.4 Productivity Trends

This section examines productivity trends for selected crops; in cereals (maize), industrial crops (tea, coffee and sugarcane), and horticulture (cabbages and Irish potatoes); and dairy sub sector. Productivity for a crop in this paper refers to quantity of the crop harvested in kilograms from one acre of land cultivated with that crop. In some instances, we show productivity for crops in terms of bags/acre (maize), kg/bush (tea) and tones/acre (sugar cane). For dairy, productivity refers to the quantity in kilogram of milk per year per milked cow. In all the cases, mean values of productivity are discussed, although median values are provided in some tables. Except for dairy, productivity for crops was computed from the main harvest (season) only for each cropping year. Short harvests (seasons) were not included in the computation.

3.4.1 Maize Productivity

The overall mean maize productivity measured in 90-kg bags per acre shows a consistent and impressive growth from 6.6 bags in 1997, 7.2 in 2000, 8.2 in 2004, to 9.3 in 2007 (Table 8). Similar findings have been reported by the Ministry of Agriculture; nationally the rising maize yield is attributed to a combination of good weather, use of improved seeds, higher fertilizer application and adoption of modern farming techniques and technologies (Economic Review of Agriculture, 2008).

The High potential maize zone, Central highlands, Western transitional and the Western highlands recorded higher level of productivity compared to the Coastal lowlands, Eastern lowlands, Western lowlands and the Marginal rain shadow. However, the lower maize productivity regions of Coastal lowlands, Eastern lowlands and Western lowlands over the decade recorded impressive increase in maize productivity per acre: from 2.0 bags in 1997 to 4.2 bags in 2007 for Coastal lowlands; from 2.3 bags in 1997 to 4.7 bags in 2007 for Eastern lowlands; and from 3.0 bags in 1997 to 5.6 bags in 2000 for Western lowlands. Maize productivity also increased from 2.1 bags/acre in 1997 to 4.6 bags/acre in 2007 for the Marginal rain shadow. The High potential maize zone, else referred to as the Kenyan grain basket, recorded maize productivity increase from 11.5 bags/acre in 1997 to 13.3 bags/acre in 2007.

Disaggregating maize yield by cropping system shows that maize productivity has been on an increasing trend for both the pure-stand and inter-crop (Table 9). Productivity for the pure-stand is, however, higher than for the inter-crop. The mean maize yield per acre for the pure-stand rose from 9.8 bags in 1997 to 11.2 bags in 2007, while that for the inter-crop rose from 6.1 bags in 1997 to 9.1 bags in 2007. It is further observed that productivity for the inter-crop maize is very close to the overall maize productivity, an indication that intercropping maize with other crops is the norm rather than the exception for smallholder maize farmers.

The density functions, showing maize yield distributions for the main and short seasons, reveal that maize productivity is generally higher in the main season than in the short season (Figure 1).

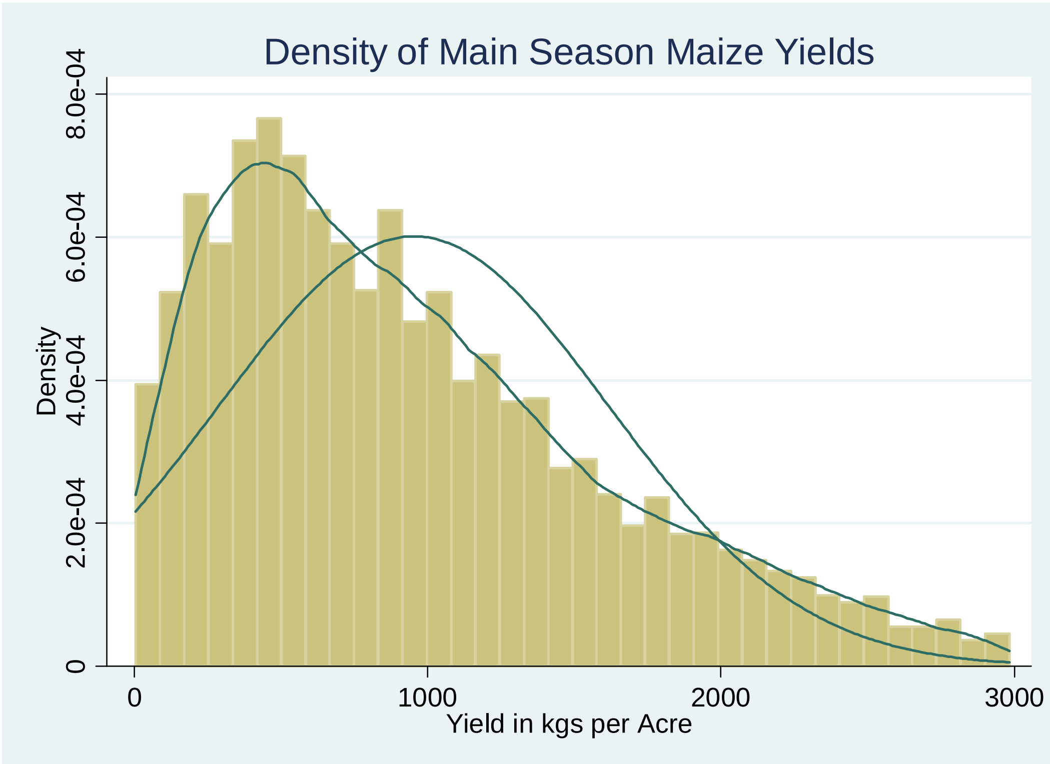
Table 8: Overall maize yield (Main Season), 1997-2007

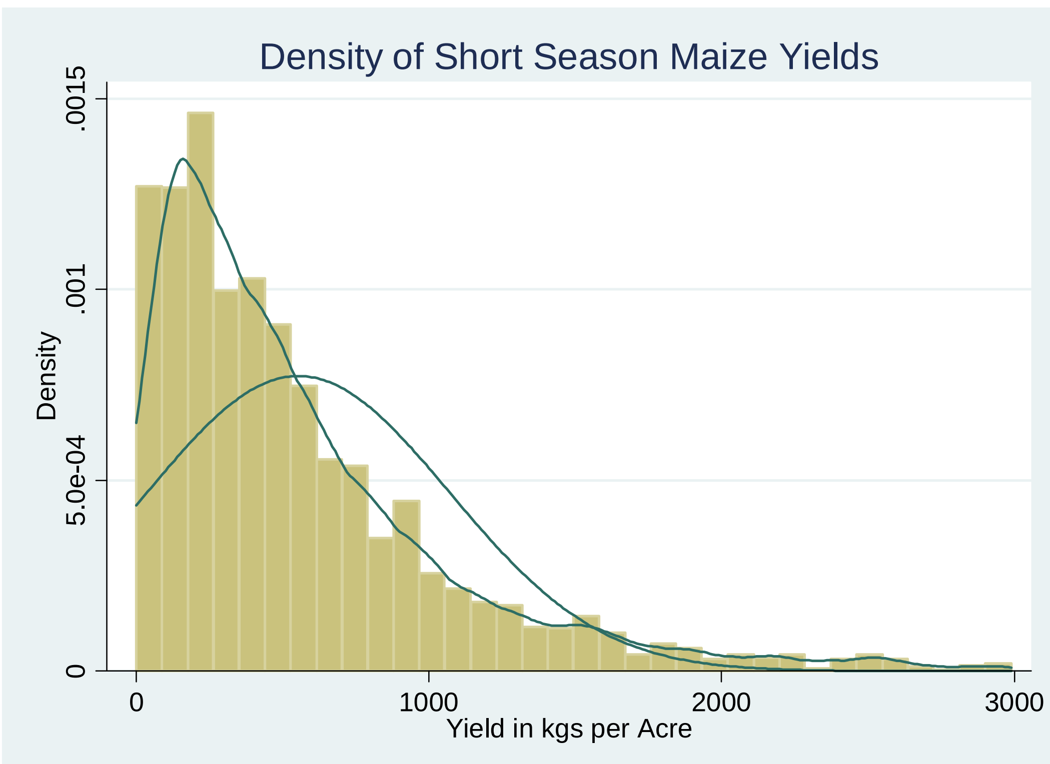
	Yield (kg/acre)		Yield (bags/acre)	
Zone	Mean	Median	Mean	Median
Coastal Lowlands				
1997	178.1	135.0	2.0	1.5
2000	361.8	303.3	4.0	3.4
2004	217.5	170.9	2.4	1.9
2007	374.0	310.2	4.2	3.4
Eastern Lowlands				
1997	206.2	90.0	2.3	1.0
2000	334.1	270.0	3.7	3.0
2004	322.6	244.0	3.6	2.7
2007	423.1	345.6	4.7	3.8
Western Lowlands				
1997	267.9	180.0	3.0	2.0
2000	233.3	180.0	2.6	2.0
2004	231.1	180.0	2.6	2.0
2007	505.8	468.9	5.6	5.2
Western Transitional				
1997	480.8	412.5	5.3	4.6
2000	677.2	592.5	7.5	6.6
2004	794.0	691.3	8.8	7.7
2007	961.0	898.1	10.7	10.0
High Potential Maize Zone				
1997	1035.5	900.0	11.5	10.0
2000	940.0	862.5	10.4	9.6
2004	1239.9	1125.0	13.8	12.5
2007	1196.2	1122.0	13.3	12.5
Western Highlands				
1997	500.4	432.0	5.6	4.8
2000	682.1	540.0	7.6	6.0
2004	597.8	510.7	6.6	5.7
2007	795.5	742.0	8.8	8.2
Central Highlands				
1997	633.3	487.5	7.0	5.4
2000	794.1	600.0	8.8	6.7
2004	829.2	675.0	9.2	7.5
2007	930.6	729.1	10.3	8.1
Marginal Rain Shadow				
1997	190.7	180.0	2.1	2.0
2000	79.6	0.0	0.9	0.0
2004	375.8	345.0	4.2	3.8
2007	409.7	307.8	4.6	3.4
Overall sample				
1997	591.1	450.0	6.6	5.0
2000	645.1	450.2	7.2	5.0
2004	737.7	562.6	8.2	6.3
2007	839.1	687.8	9.3	7.6

Table 9: Pure stand and intercrop maize yield (Main season), 1997-2007

	Pure stand maize				Intercrop maize			
	Yield (kg/acre)		Yield (bags/acre)		Yield (kg/acre)		Yield (bags/acre)	
Zone	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Coastal Lowlands								
1997	176	126	2.0	1.4	177	135	2.0	1.5
2000	471	459	5.2	5.1	360	292	4.0	3.2
2004	169	90	1.9	1.0	221	173	2.5	1.9
2007	348	334	3.9	3.7	378	310	4.2	3.4
Eastern Lowlands								
1997	438	133	4.9	1.5	161	90	1.8	1.0
2000	602	443	6.7	4.9	309	251	3.4	2.8
2004	562	390	6.2	4.3	264	234	2.9	2.6
2007	447	325	5.0	3.6	415	343	4.6	3.8
Western Lowlands								
1997	300	248	3.3	2.8	269	180	3.0	2.0
2000	600	296	6.7	3.3	231	180	2.6	2.0
2004	233	180	2.6	2.0	251	189	2.8	2.1
2007	528	348	5.9	3.9	508	474	5.6	5.3
Western Transitional								
1997	502	450	5.6	5.0	487	405	5.4	4.5
2000	927	720	10.3	8.0	675	562	7.5	6.2
2004	740	700	8.2	7.8	806	692	9.0	7.7
2007	889	758	9.9	8.4	974	921	10.8	10.2
High Potential Maize Zone								
1997	1442	1,365	16.0	15.2	943	900	10.5	10.0
2000	1006	900	11.2	10.0	941	900	10.5	10.0
2004	1444	1,350	16.0	15.0	1234	1125	13.7	12.5
2007	1265	1,139	14.1	12.7	1165	1118	12.9	12.4
Western Highlands								
1997	486	431	5.4	4.8	508	450	5.6	5.0
2000	657	486	7.3	5.4	680	540	7.6	6.0
2004	1063	1,471	11.8	16.3	601	511	6.7	5.7
2007	623	578	6.9	6.4	798	746	8.9	8.3
Central Highlands								
1997	727	720	8.1	8.0	627	450	7.0	5.0
2000	1130	937	12.6	10.4	757	557	8.4	6.2
2004	770	720	8.6	8.0	814	667	9.0	7.4
2007	979	958	10.9	10.6	917	710	10.2	7.9
Marginal Rain Shadow								
1997	-	-	-	-	191	180	2.1	2.0
2000	240	-	2.7	-	65	0	0.7	-
2004	240	240	2.7	2.7	374	345	4.2	3.8
2007	-	-	-	-	410	308	4.6	3.4
Overall sample								
1997	883	720	9.8	8.0	551	420	6.1	4.7
2000	862	653	9.6	7.3	635	450	7.1	5.0
2004	940	724	10.4	8.0	731	555	8.1	6.2
2007	1004	900	11.2	10.0	818	663	9.1	7.4

Figure 1: Density Function of Maize Yields





3.4.2 Factors driving maize productivity growth

The impressive growth in maize productivity could be attributed to several factors, including increased input use and physical and market infrastructural developments. Some of these factors are discussed in the following sub-sections.

3.4.2.1 Use of high yielding maize varieties

The quality of planting material has a significant impact on crop productivity. The limited potential for further expansion of area under maize cultivation due to diminishing availability of arable land implies that future growth in maize production would have to depend on yield gains made by wide-spread use of productivity-enhancing technologies, among which include high yielding varieties (HYVs). Results show a general increasing trend in the proportion of households planting HYVs over the panel period from 70% in 1997, 69% in 2000 and 2004 and 74% in 2007 (Table 10). However, analysis by zone reveals increasing, stagnating or declining trends in adoption of HYVs. Some of the agro-regional zones that have recorded a progressive increase in the proportion of households using HYVs are; Western transition (from 74% in 1997 to 87% in 2007); High potential maize zone (from 89% in 1997 to 94% in 2007); Western highlands (from 75% in 1997 to 83% in 2007) and Western lowlands (from 14% in 1997 to 32% in 2007).

Proportion of households using HYVs in the lower maize productivity regions of Coastal lowlands and Eastern lowlands have stagnated at 44% and 53%, respectively. On the contrary, in the Central highlands and Marginal rain shadow, the proportion of households that planted HYVs on maize declined from 89% in 1997 to 83% in 2007 and 89% in 1997 to 65% in 2007, respectively. The uniquely declining adoption levels of HYVs' in Central highlands and Marginal rain shadow over the panel period could be a pointer to declining importance attached to maize enterprise in the regions. Nationally, quantity of improved maize seed used rose by 13% from 45,000 metric tonnes in 1996/97 to 51,000 metric tonnes in 2006/07 (Economic review of Agriculture, 2008, FAOSTAT)- Annex 2.

Table 10: Percent of Households that Planted High Yielding Maize Varieties (Main season), 1997-2007

Agro-regional zone	**1997**		**2000**		**2004**		**2007**	
	No. of hhs	%	No. of hhs	%	No. of hhs	%	No. of hhs	%
Coastal Lowlands	29	44	30	45	27	39	29	44
Eastern Lowlands	79	54	56	39	59	41	76	53
Western Lowlands	22	14	36	24	41	27	48	32
Western Transitional	110	74	109	74	110	75	126	86
High Potential Maize Zone	306	89	304	88	308	90	322	94
Western Highlands	96	75	103	80	98	76	106	83
Central Highlands	215	89	211	87	204	85	201	83
Marginal Rain Shadow	32	89	28	76	28	76	24	65
National sample	**889**	**70**	**877**	**69**	**875**	**69**	**932**	**74**

3.4.2.2 Combined use of high yielding maize varieties and fertilizer

While HYVs contribute towards improved crop yields, their use must be supplemented by other productivity enhancing inputs, mainly fertilizer, to exploit their full productivity potential. Analysing patterns in simultaneous use of fertilizer and HYVs on maize can shed more light on the observed productivity trends and provide information that can be useful in proposing measures to improve agricultural productivity. Table 11 presents that analysis. There is a consistent general increase in the proportion of households combining fertilizer and HYVs for maize across the zones and the panel period, from 51% in 1997 to 61% in 2007 (Table 11).

Regionally, there are distinct variations in the rate of adoption of the combined fertilizer-improved seed package. An impressive increase in the proportion of households combining use of fertilizer and HYVs is observed over the panel period in Eastern lowlands (from 16% in 1997 to 31% in 2007), Western transitional (37% in 1997 to 74% in 2007), High potential maize zone (77% in 1997 to 88% in 2007) and Western highlands (70% in 1997 to 82% in 2007). Adoption of fertilizer and HYVs doubled in Western transitional, and this is reflecting on maize productivity in the region, which has consistently increased, and more than doubled over the panel period.

The Coastal and Western lowland regions have the lowest (less than 9%) adoption levels of combined fertilizer and HYVs on maize. With adoption levels of HYVs only ranging between 2% in 1997 and 8% in 2007 in Coastal lowlands and 1% in 1997 and 37% in 2007 in Western lowlands, it means that the majority of users of HYVs on maize in the two regions do not use the combination. These semi-arid regions are where rainfall is least reliable and where soil organic matter is commonly a problem, reinforcing low returns and high risks to fertilizer application. These areas are hence where maize productivity is lowest. Recent analysis by Marenya and Barrett (2008) also underscores the importance of soil organic matter in limiting fertilizer use in these areas. Their analysis concludes that "farmers cultivating more degraded soils may find it unprofitable to invest in soil nutrient inputs, not necessarily because the fertilizer/crop price ratio is too high or due to credit, information or risk constraints, nor because of supply-side impediments that limit fertilizer's physical availability, but because marginal yield response to nitrogen application is low on carbon-deficient soils" (p. 24).

Findings in Table 11 also show a slight decline in the use of the combined fertilizer/HVY package in the Central highlands and Marginal rain shadow. This trend is mainly reflecting the decline in HYV use as shown in Table 10.

Table 11: Number and Percent of Households Combining Fertilizer *and* High Yielding Maize Varieties (main season)

Agro-regional zone	1997		2000		2004		2007	
	No. of hhs	%	No. of hhs	%	No. of hhs	%	No. of hhs	%
Coastal Lowlands	1	2	4	6	3	4	5	8
Eastern Lowlands	23	16	24	17	42	29	44	31
Western Lowlands	1	1	2	1	9	6	10	7
Western Transitional	55	37	86	58	94	64	109	74
High Potential Maize Zone	265	77	276	80	279	81	302	88
Western Highlands	89	70	98	76	98	76	105	82
Central Highlands	202	83	201	83	193	80	190	79
Marginal Rain Shadow	2	6	5	14	4	11	4	11
National sample	**638**	**51**	**696**	**55**	**722**	**57**	**769**	**61**

Note: total sample contains 1,275 households.

3.4.2.3 Development and Adoption of New Maize Varieties

Enhanced availability of HYVs has been fuelled by the liberalization of the seed market. By 2004 there were 14 registered maize seed companies. Between 1994 and 2003 a total of 71 maize cultivars (11 from public sector and 60 from the private sector) were released into the market (MoA, 2004). The benefit of liberalisation of the seed market is traced in the panel analysis. The number of maize seed varieties planted by the households increased between 2004 and 2007 in all the agro-regional zones (Table 12).

Western highlands registered the highest number of maize seed varieties from 9 to 18 (100% increase). The Western lowlands and Western transitional zones also saw a significant increase in the number of seed varieties by 75% and 59%, respectively. There was also a significant increase in number of seed varieties in Central highlands (by 76%) and Marginal Rain Shadow (by 64%). The High potential maize zone, Eastern lowlands and Coastal lowlands had the lowest increase in the number of varieties of 39%, 36% and 33%, respectively. These trends are indications that maize growing households have many seed varietal alternatives from which to choose, and further explain the high adoption levels of HYVs.

Table 12: Number of maize seed varieties planted by households by region

Agro-regional zone	2004	2007	% change
Coastal Lowlands	6	8	33
Eastern Lowlands	11	15	36
Western Lowlands	12	21	75
Western Transitional	17	27	59
High Potential Maize Zone	23	32	39
Western Highlands	9	18	100
Central Highlands	17	30	76
Marginal Rain Shadow	11	18	64
National sample	**38**	**70**	**84**

3.4.2.4 Fertilizer use

Expanding fertilizer use is widely considered to be a pre-condition for broad-based farm productivity growth. Profitability of fertilizer use is, however, dependent on several factors, one being agro-ecological conditions (Marenya and Barrett, 2008). The differences in agro-ecological conditions facing Kenyan small-scale farmers have contributed to variations in fertilizer use among different regions. Table 13 shows trends in fertilizer adoption by households during the panel period. In general, the proportion of households using fertilizer has risen from 64% in 1997 to 76% in 2007, a 20% increase over this ten year period.

The largest growth in the proportion of households using fertilizer over the decade is observed in the semi-arid regions of Western Lowlands (400%), Coastal Lowlands (300%), Marginal Rain Shadow (440%) and Eastern Lowlands (63%). The High Potential Maize zone and Western Highlands have the lowest growth in fertilizer adoption rate of 9% and 3% during the panel period, because most farmers in these zones were already using fertilizer in 1997. It is important to note that the Central highlands region has not registered any growth in the proportion of households using fertilizer. Instead, it has recorded a decline in fertilizer adoption from 99% in 1997 and 2000 to 97% in 2004 and 2007.

The proportion of households using fertilizer in the semi-arid regions was comparatively lower (3% - 57%) compared to high potential agricultural regions (58% - 100%) during the panel period.

Table 13: Percent of Households using Fertilizer (main and short season), By Region and Year

Zone	**1997**		**2000**		**2004**		**2007**	
	No. of hhs	%	No. of hhs	%	No. of hhs	%	No. of hhs	%
Coastal Lowlands	2	2.7	5	6.8	6	8.0	9	12.3
Eastern Lowlands	51	35.2	70	48.3	82	56.6	82	56.6
Western Lowlands	9	5.9	18	11.8	23	15.0	46	30.5
Western Transitional	86	58.1	114	77.0	127	85.8	130	87.8
High Potential Maize Zone	298	86.1	313	90.5	313	90.5	323	93.6
Western Highlands	118	91.5	116	89.9	119	92.2	122	94.6
Central Highlands	240	99.2	241	99.6	235	97.1	237	97.9
Marginal Rain Shadow	10	27.0	13	35.1	12	32.4	20	54.1
National sample	**814**	**63.9**	**890**	**69.9**	**917**	**71.9**	**969**	**76.3**

Note: full sample contains 1,275 households.

Regional analysis of fertilizer use patterns provides insight into how agro-ecological differences affect fertilizer use by influencing profitability of use. Disaggregating households' fertilizer use patterns by crop sheds more light on the crops that account for growth in fertilizer use, and gives an indication of which fertilizer distribution systems are responsible for the patterns, since in Kenya different crops are managed under specific input distribution systems.

The number of households producing maize has remained high and about the same over the panel period, pointing to the importance attached to maize by the smallholder farmers. The proportion of these households using fertilizer on maize consistently increased during the panel period from 57% in 1997, 63% in 2000, 67% in 2004, to 71% in 2007 (Table 14). This represents a 24% increase in the proportion of households using fertilizer on maize over the 1997-2007 period.

Table 14: Percent of households using fertilizer on maize by region (main and short season)

Zone	1997		2000		2004		2007	
	No. of hhs	%	No. of hhs	%	No. of hhs	%	No. of hhs	%
Coastal Lowlands	2	3	4	6	5	7	8	12
Eastern Lowlands	41	28	49	34	71	49	81	56
Western Lowlands	3	2	8	5	11	7	18	12
Western Transitional	60	41	95	64	105	71	123	84
High Potential Maize Zone	289	84	307	89	305	89	316	92
Western Highlands	102	80	111	86	118	91	121	95
Central Highlands	224	93	223	92	223	93	219	91
Marginal Rain Shadow	3	8	5	14	4	11	6	16
National sample	**724**	**57**	**802**	**63**	**842**	**67**	**892**	**71**

Note: full nationwide sample contains 1,275 households.

Intensity of fertilizer application on maize has, on the contrary, fluctuated between 55kg and 60kg per acre over the panel period (Table 15). The general increasing trend in maize productivity can, therefore, be attributed more to increased adoption of fertilizer than to intensity of use, by maize farmers.

Table 15: Fertilizer use rate (kg/acre) on maize (users only), main season

Zone	1997	2000	2004	2007
Coastal Lowlands	11	5	3	7
Eastern Lowlands	10	18	15	16
Western Lowlands	24	14	10	12
Western Transitional	54	48	62	71
High Potential Maize Zone	65	67	74	75
Western Highlands	31	36	46	47
Central Highlands	**68**	**64**	**64**	**58**
Marginal Rain Shadow	12	15	43	43
National sample	**56**	**55**	**60**	**59**

A more detailed analysis of fertilizer use patterns on maize is presented on Table 16. The trends show an overall decline in the proportion of households using lower quantities of fertilizer (less than 25kg per acre) from 31% in 1997, 30% in 2000 and 2004, to 28% in 2007. This decreasing trend is more pronounced in the Western highlands. On the contrary, in the Coastal lowlands, all the households that use fertilizer have applied less than 25 kg/acre across the panel years. Compared to other regions, the intensity of use is lowest in the Coastal lowlands, Eastern lowlands, Western lowlands and the Marginal rain shadow.

A similar trend is observed in the category of farmers using fertilizer quantities that range from 25kg/acre to 50 kg/acre. The proportion of households in this category has declined from 35% in 1997, 33% in 2000 to 29% in 2004 and 2007. The proportion of households applying more than 50kg /acre has increased consistently from 34% in 1997, 37% in 2000, 41% in 2004 to 43% in 2007.

Nationally, quantity of chemical aggregated fertilizer in Kenya used rose by 65 % from 255,000 metric tonnes in 1996/97 to 411,000 metric tonnes in 2006/07 (Economic review of Agriculture, 2008, FAOSTAT) - Annex 2.

Table 16: Intensity of fertilizer application on maize by zone (main season), 1997-2007

	% of households											
	1997			**2000**			**2004**			**2007**		
Agroregional zone	**>0 and <=25kg**	**>25 and <=50 kg**	**>50kg**	**>0 and <=25kg**	**>25 and <=50 kg**	**>50kg**	**>0 and <=25kg**	**>25 and <=50 kg**	**>50kg**	**>0 and <=25kg**	**>25 and <=50 kg**	**>50kg**
Coastal Lowlands	100			100			100			100		
Eastern Lowlands	90	10		80	10	10	86	10	4	83	12	5
Western Lowlands	67		33	88		13	100			94	6	
Western Transitional	25	37	38	35	33	33	27	28	46	26	20	54
High Potential Maize Zone	11	49	40	14	41	45	12	36	51	13	32	55
Western Highlands	57	29	14	47	33	20	38	29	33	25	39	36
Central Highlands	33	25	42	25	30	46	26	29	45	25	34	41
Marginal Rain Shadow	100			80	20		50		50	50	33	17
All zones	**31**	**35**	**34**	**30**	**33**	**37**	**30**	**29**	**41**	**28**	**29**	**43**

Further analysis show that the use of organic fertilizer (farmyard and compost manure) is also rising in importance across the zones, and reflects farmers' attempts to raise soil fertility. The proportion of households using organic fertilizer increased from 44% in 2000 to 50% in 2007 (Table 17). The Central highlands region has the highest proportion of households using organic fertilizers. This could probably explain why maize productivity has increased in the region despite a decline in use rate of inorganic fertilizers on maize in that zone; from 68kg/acre in 1997 to 58kg/acre in 2007

Table 17: Percent households using organic fertilizer during the year, 2000-2007

Zone	2000	2004	2007
Coastal Lowlands	29	34	32
Eastern Lowlands	75	80	83
Western Lowlands	19	25	36
Western Transitional	44	33	44
High Potential Maize Zone	22	22	24
Western Highlands	38	35	23
Central Highlands	**73**	**92**	**95**
Marginal Rain Shadow	76	68	68
Overall Sample	**44**	**47**	**50**

In spite of the impressive growth in the adoption of fertilizer, the study shows that 17% of the households in the sample did not use fertilizers in any of the panel years. Of theses households 80% are in the Coastal, Eastern and Western lowlands, areas where fertilizer application is often relatively risky and in places unprofitable due to erratic rainfall and poor soil fertility. Some of these semi-arid regions are only marginally suitable for crop production. In these relatively disadvantaged areas, 80% of the households in the full sample are also in the lowest income group.

Asked why they did not use fertilizer, 47% of the consistent non-users of fertilizer gave inability to afford fertilizer as the reason. About 20% of the non-users said they prefer to use organic fertilizer, while 8% said they lack technical advice on fertilizer usage.

3.4.2.5 Reduced Distances to Input Stockists

Distance to the market, both for inputs and output, has been found to be a key issue in productivity analysis. Omamo (1998) found that distance to the market and related transportation costs affect crop choice decisions. Distance to particularly inputs markets has a bearing on the inputs' use and, consequently productivity. Table 18 shows a general decline in the mean distance to nearest fertilizer stockist, from 8km in 1997 to 3km in 2007. This trend is mirrored across all the regional zones. Central highlands, Western highlands, High potential maize zone and Western transitional regions in that order have the shortest and declining distances to the nearest fertilizer stockist over the period. It is noteworthy that fertilizer adoption in these regions is higher compared to the Lowlands and the Marginal rain shadow. The Lowlands and the Marginal rain shadow have equally declining distances to the fertilizer stockist over the panel period, but the distances are longer than in the other regions for all the years except 2007. Coastal lowlands has the longest (though declining) mean distances of 31km in 1997, 24km in 2000, 18km in 2004 and 11km in 2007. It is in this region where fertilizer adoption level is lowest. The general decline in distance to fertilizer stockist is consistent with the International Fertilizer Development Centre (IFDC)'s (2001) finding that the number of fertilizer retailers in Kenya expanded tremendously after the fertilizer market was deregulated.

A similar trend is observed for distances to the nearest hybrid maize seed stockist, which generally declined from 6km in 2000 to 3km in 2007. The Highlands, Western Transitional and High potential maize zone regions have the shortest and generally declining distances. The Lowlands and Marginal rain shadow have the longest albeit declining distances. In all the regions, except Coastal lowlands, the distances to hybrid maize supplier reported were highest for 2004.

Table 18: Mean Distance to fertilizer and hybrid maize seed stockist

	Distance to fertilizer stockist				**Distance to hybrid maize seed stockist**		
Zone	**1997**	**2000**	**2004**	**2007**	**2000**	**2004**	**2007**
Coastal Lowlands	30.6	24.3	18.4	11.3	21.8	18.7	9.5
Eastern Lowlands	9.8	5.4	4.2	2.7	6.4	3.7	3.0
Western Lowlands	16.0	11.6	7.5	3.8	9.1	5.4	3.8
Western Transitional	6.3	4.6	2.8	3.6	4.2	2.7	3.7
High Potential Maize Zone	5.0	4.0	3.0	3.6	4.5	3.0	3.7
Western Highlands	3.3	2.2	1.4	2.4	2.6	1.6	2.4
Central Highlands	2.7	1.5	1.4	1.3	1.9	1.5	1.5
Marginal Rain Shadow	26.2	5.8	5.4	2.3	5.2	4.3	2.3
National sample	**8.1**	**5.7**	**4.1**	**3.4**	**5.6**	**3.9**	**3.4**

To summarize, there has been a consistent increase in smallholder fertilizer use in Kenya over the past decade. This increase may be attributed to several factors: (a) increased accessibility of fertilizer by smallholder farmers due to availability of the input in small packs that more farmers can afford; (b) reduction in the distance from the household to the nearest fertilizer stockist, reflecting increased investment in private fertilizer retailing; (c) a reduction in real fertilizer prices in Kenya up to 2007, reflecting reduced marketing costs in fertilizer marketing costs (Ariga, Jayne and Nyoro, 2006) – this trend has been reversed since 2007 with the dramatic rise in world fertilizer prices; and (d) more farmers have been organized into groups, providing a variety of benefits such as group loans for input purchase, information to improve farmers' management practices such as soil testing services, increased awareness of fertilizers' role in increasing maize productivity, and information on how and when to apply fertilizer efficiently. This growth in smallholder fertilizer use in general, and on maize in particular, has occurred during a period when real maize prices, ironically, have declined significantly during the 1997-2007 period.

3.4.3 Tea Productivity

During the panel period, there was a marginal increase in the mean tea productivity of 15% from 3,931 kg/acre (1.12 kg/tea bush) in 1997 to 4,507 kg/acre (1.29 kg/tea bush) in 2007 of green leaf tea (Table 19). However, in 2000, productivity was lowered by drought. Tea productivity was driven by the Western regions; Kisii and Vihiga districts. In Kisii, tea productivity doubled from 0.61 kg/tea bush in 1997 to 1.22 kg/bush in 2007, while in Vihiga a similar trend was observed where productivity grew from 0.26 kg/bush in 1997 to 1.3 kg/bush in 2007. Tea productivity in parts of Central highlands such as Murang'a and Nyeri has remained fairly constant during the panel period. However, the Central highland has maintained highest level of productivity.

Table 19: Mean Annual Tea Productivity, 1997- 2007

Agro-regional zone	District	Year	Mean Productivity per acre	Mean Productivity per tea bush	Mean area under tea
High Potential Maize Zone	Bomet	1997	4,017	1.15	1.40
		2000	3,765	1.08	1.52
		2004	3,878	1.11	1.77
		2007	3,704	1.06	1.88
Western Highlands	Kisii	1997	2,142	0.61	0.49
		2000	3,154	0.90	0.33
		2004	3,358	0.96	0.37
		2007	4,278	1.22	0.48
	Vihiga	1997	897	0.26	0.67
		2000	1,624	0.46	0.70
		2004	2,642	0.75	0.47
		2007	4,549	1.30	0.45
Central Highlands	Meru	1997	4,364	1.25	1.05
		2000	4,444	1.27	0.80
		2004	5,510	1.57	0.80
		2007	5,147	1.47	0.78
	Muranga	1997	4,722	1.35	0.47
		2000	4,461	1.27	0.45
		2004	4,215	1.20	0.44
		2007	4,674	1.34	0.43
	Nyeri	1997	4,653	1.33	1.41
		2000	4,295	1.23	1.50
		2004	4,514	1.29	1.42
		2007	4,706	1.34	1.43
Overall		1997	3,931	1.12	1.08
		2000	3,869	1.11	1.04
		2004	4,206	1.20	1.01
		2007	4,507	1.29	1.05

Overall, the mean area under tea production per household has fairly remained constant at 1 acre. However, there is a slight but consistent decline in the area under tea production in Meru (1.08 acres in 1997 to 0.78 acres in 2007) and in Muranga (0.47 acres in 1997 to 0.43 acres in 2007). A similar trend is observed in Vihiga, where the mean area has declined from 0.67 acres in 1997 to 0.45 acres in 2007. This could be associated with increasing fragmentation of land as a result of population pressure.

The tea sector is currently facing many challenges such as global oversupply of tea, high cost of production, concentration on a few traditional markets, inefficiencies in the management of small holder tea sub-sector, among others. However, the major challenge is the weakening of the dollar, which has led to lower tea returns in the recent past. For example, the average price per kilogram of made tea declined from USD 2.11 in 2000 to USD 1.76 in 2007. Additionally, small land sizes under tea (over 50% of the households have less than 1 acre under tea) pose a big challenge to the tea sector.

3.3.1 Factors driving growth in tea productivity

Fertilizer adoption rate in tea consistently rose from 84% in 1997 to 98% in 2007, an average growth of 16% over the ten years (Table 20). Regionally, Western highland districts of Kisii and Vihiga recorded the highest growth in fertilizer adoption compared to other districts. The proportion of households applying fertilizer on tea increased in Kisii from 70% to 94% during the decade, while in Vihiga fertilizer adoption on tea by households rose from 64% in 1997 to 94% in 2007. In Nyeri, Muranga, Nyeri and Bomet districts, the proportion of households applying fertilizer on tea has generally remained above 90% over the decade.

Fertilizer application rate on tea has, however, declined by 4% over the period, from 385 kg/acre in 1997 to 373 kg/acre in 2007. Regional analysis, however, shows disparities in trends in the application rate. Kisii and Vihiga districts show increasing trends in fertilizer application rates on tea from a mean of 241 kg/acre in 1997 to 360 kg/acre in 2007 and 124 kg/acre in 1997 to 394 kg/acre in 2007, respectively. Increasing trends in fertilizer application rate is also observed in Meru (from 410 kg/acre to 419 kg/acre) and Muranga (from 287 kg/acre to 499 kg/acre) over the decade. Bomet and Nyeri districts, however, registered a decline in fertilizer application rate in tea from 298 kg/acre to 264 kg/acre and from 545 kg/acre to 382 kg/acre, respectively, between 1997 and 2007. It is worth noting that Western highland districts of Kisii and Vihiga where growth in fertilizer adoption and application rates were highest also registered the highest growth in tea productivity during the panel period. The fertilizer distribution system in the tea sector is the reason behind the impressive performance in fertilizer adoption on tea. Kenya Tea Development Agency (KTDA) supplies fertilizer on credit to smallholder tea farmers and then deducts the cost plus interest from their deliveries of tea, which is sold by KTDA on behalf of the farmers.

Table 20: Application rates of and percent of households applying fertilizer on tea

[redacted]

3.4 Coffee Productivity

Coffee productivity rose from a mean of 1,459 kg/acre in 1997, before declining consistently to 1,826 kg/acre in 2000, 1,577 kg/acre in 2004 and 1,285 kg/acre (Table 21). This trend is observed across the agro-regional zones, although, in some cases there is no clear trend observed.

Table 21: Trends in Productivity of Green Coffee, 1997-2007

Zone	Year	Productivity kg /acre	Mean area under production
Eastern Lowlands	1997	790	0.93
	2000	326	0.67
	2004	134	0.70
	2007	432	0.77
Western Lowlands	1997	279	0.71
	2000	429	0.17
	2004	569	0.69
	2007	321	0.07
Western Transitional	1997	800	0.25
	2000	262	0.15
	2004	176	0.16
	2007	41	0.26
High Potential Maize Zone	1997	551	0.68
	2000	539	0.45
	2004	352	0.53
	2007	357	0.46
Western Highlands	1997	986	0.44
	2000	1,285	0.62
	2004	1,849	0.35
	2007	993	0.37
Central Highlands	1997	1,933	0.55
	2000	2,616	0.52
	2004	1,810	0.54
	2007	1,639	0.53
Overall	1997	1,459	0.56
	2000	1,826	0.55
	2004	1,577	0.49
	2007	1,285	0.48

3.4.1 Factors contributing to decline in coffee productivity

The gloomy picture of the once vibrant coffee sector is a result of international market forces such as declining prices of world coffee in the early 1990's, mismanagement of coffee co-operatives and high cost of production. The farm level production costs have escalated in the recent past. The high costs of production of coffee have exposed producers further to the world coffee price risks and fluctuation. Coffee production, particularly by the small-scale producers, is likely to remain low unless there are improvements in farm productivity and coffee prices, as well as a reduction of transaction costs. Making new hybrids that are resistant to diseases available for adoption by farmers could reduce production costs. Availability of these varieties has, however, been constrained in the past by restricted multiplication of the seeds and seedlings by the Coffee Research Foundation (Nyoro et al 2001).

The proportion of households using fertilizer on coffee rose from 44% in 1997 to 51% in 2000, and then took a downward turn to 45% in 2004 (Table 22). In 2007, only 37% of households producing coffee used fertilizers. The decline in proportion of households using fertilizer on coffee averaged 16% over the panel period. Fertilizer application rate on coffee indicates an average of 20% decline over the panel period. A closer look reveals that the application rate consistently declined from 364 kg/acre in 2000, to 256 kg/acre in 2004, to 147 kg/acre in 2007, an average decline of 148% in a span of seven years. The gloomy picture in fertilizer use patterns on coffee is as a result of two main factors: alleged mismanagement of coffee cooperatives, which are the main channels through which members receive their fertilizer; and poor international coffee prices. Mismanagement in the cooperatives has made some farmers abandon coffee production while other farmers have opted to directly access fertilizers from private traders. This has made them disadvantaged in that they no longer access input credit facilities offered by the cooperatives as was the custom during the days when the cooperative movements were active and efficiently run.

Table 22: Mean application rates of and percent of households applying fertilizer on coffee

	1997	**2000**	**2004**	**2007**
kgs/acre cultivated (users only)	183	364	256	147
% of households using fertilizer	**44**	**51**	**45**	**37**
No. of households producing coffee	257	308	283	250

3.5 Sugar cane Productivity

The overall sugar cane productivity per acre increased from 27 tonnes in 1997 to 30 tonnes in 2004, but declined to 24 tonnes (Table 23). The mean area under production per household has remained at 2 acres; however, there was a slight increase in acreage from 2 acres to 2.5 acres in 2007.

Table 23: Mean Sugar cane Productivity, 1997-2007

Zone	District	Year	Mean productivity in Tonne/acre	Mean Area under production per household
Western Lowlands	Kisumu	1997	18.1	1.93
		2000	15.9	2.10
		2004	15.7	2.51
		2007	27.4	1.70
Western Transitional	Bungoma	1997	50.7	2.49
		2000	40.2	2.45
		2004	39.6	2.10
		2007	27.4	3.48
	Kakamega	1997	23.1	2.25
		2000	28.9	2.10
		2004	28.9	1.85
		2007	23.4	2.33
Overall mean		1997	27.0	2.18
		2000	29.6	2.18
		2004	29.9	2.03
		2007	24.8	2.50

3.5.1 Factors contributing to stagnating productivity of sugarcane

Fertilizer adoption on sugarcane over the ten-year period showed an impressive average growth of 138%, the highest of all the four crops (Table 24). The proportion of households using fertilizer on sugarcane grew from a low of 29% in 1997 to stand at 69% in 2007. Regional analysis show that fertilizer use on sugar cane expanded in all the sample districts growing sugar cane. The proportion of households applying fertilizer on sugar cane rose from 8% to 37% in Kisumu, 40% to 95% in Bungoma, and 31% to 68% in Kakamega, between 1997 and 2007. The trends reveal that Western lowlands lags behind Western Transitional in fertilizer use on sugarcane in the Western sugar belt.

Fertilizer application rate on sugarcane declined from 118 kg/acre in 1997 to 110 kg/acre in 2007. Kisumu and Bungoma districts, however, recorded an increase in fertilizer application rate on sugar cane from 67 kg/acre to 119 kg/acre and 85 kg/acre and 108 kg/acre, respectively, between 1997 and 2008. In Kakamega, fertilizer application rate fell from 140 kg/acre in 1997 to 111 kg/acre in 2007.

Increased fertilizer adoption in smallholder sugarcane farming can be attributed to provision on credit of fertilizer and other inputs to smallholder cane farmers by the cooperatives to which the farmers belong. The dwindling fertilizer application rate, however, is a cause to worry about, since it may smother the expected gains from increasing rate of adoption. Declining application rate may be as a result of inadequate supply of fertilizer by the cooperatives relative to farmers' demand, or it may be as a result of farmers' diversion of fertilizer acquired from the cooperatives from use on sugarcane to use on other crops. The latter has been alleged by Ariga, *et al* (2006), who posited that some of the fertilizer acquired for intended use on the cash crops such as coffee and sugarcane under cooperative schemes is appropriate for use on maize and most horticultural crops as well, and there is likely to be some diversion of fertilizer targeted for use on sugarcane and coffee to food crops.

Table 24: Mean application rates of and percent of households applying fertilizer on sugar cane

[redacted]

3.6 Cabbage Productivity

Cabbages are produced in all the agro-regional zones but by a few households per zone. In order to improve the precision of the information on cabbages, we analyze trends for producers in the High potential maize zones and the Central highlands, where the number of households producing cabbages is above than 30. The overall mean cabbage productivity measured in kilograms produced per acre has fluctuated across the panel period from 7,464 in 1997; 9,269 in 2000; 8,184 in 2004; to 9,222 in 2007 (Table 25). However, the area allocated to cabbage production for the two agro regional zones declined from 0.37 acre in 1997 to 0.17 acre in 2007. An important observation is that the number of farmers producing cabbages in Central highlands increased by 50% from 61 farmers to 92 farmers between 1997 and 2007.

Table 25: Cabbage Productivity, 1997-2007

Zone	No. of households producing cabbages	Year	Mean productivity	Mean Acreage
High Potential Maize Zone	31	1997	8,948	0.34
	112	2000	7,188	0.20
	81	2004	3,304	0.18
	45	2007	5,338	0.17
Central Highlands	65	1997	6,783	0.38
	91	2000	11,829	0.29
	79	2004	13,187	0.18
	93	2007	11,101	0.17
Overall	96	1997	7,464	0.37
	203	2000	9,269	0.24
	160	2004	8,184	0.18
	138	2007	9,222	0.17

3.7 Irish Potato Productivity

Potatoes are produced in most agro-regional zones, but mainly in the High potential maize zone and the Central highlands. In order to improve precision of the information on potatoes, we analyze trends for producers in the two zones, where the number of households producing potatoes was more than thirty.

The overall mean potato productivity does not show a particular trend (Table 26). The mean acreage allocated to potatoes has stagnated at 0.25 acre per household. However the number of households producing potatoes has increase by 64% in the high potential maize zone and 22% in the central highlands during the panel period. Irish potato faces challenges of proliferation of soil borne diseases and unavailability of clean planting materials (Economic Review of Agriculture, 2008).

Table 26: Potato Productivity, 1997- 2007

Zone	Year	Mean productivity	Mean acreage	N
High Potential Maize Zone	1997	2,526	0.58	85
	2000	4,291	0.68	190
	2004	2,651	0.48	182
	2007	3,013	0.54	140
Central Highlands	1997	2,398	0.49	179
	2000	5,169	0.51	212
	2004	2,860	0.43	219
	2007	2,810	0.34	219
Overall	1997	2,440	0.52	264
	2000	4,752	0.59	402
	2004	2,765	0.45	401
	2007	2,889	0.42	359

3.8 Dairy Productivity

The dairy sub –sector has also experienced a significant growth in milk productivity per cow. Generally, the mean annual milk productivity declined from 1164 liters/cow in 1997 to 1079 liters/cow in 2000 (Table 27). This decline could be associated with the drought in 1999/2000 cropping year. But since then, milk productivity grew steadily to 1298 liters/cow in 2004 to 1371 liters/cow in 2007. This trend is observed in all the agro-regional zones.

The Central highlands zone has the highest level of milk productivity and has grown steadily from 1856 liters/cow in 1997 to 1991 liters/cow in 2007. The High potential maize zone is the second milk producing region, but with lower level of productivity rising from 1269 liters/cow in 1997 to 1692 liters/cow in 2007. The Western transition, Western highlands and the Marginal rain shadow form the medium productivity regions, while the Coastal and Western lowlands recorded the lowest level of milk productivity.

Table 27: Cow milk mean productivity (liters/cow) per year by zone, 1997-2007

Agro-regional zone	**1997**	**2000**	**2004**	**2007**
Coastal Lowlands	139	418	207	701
Eastern Lowlands	688	856	785	890
Western Lowlands	327	360	367	367
Western Transitional	677	662	812	1,022
High Potential Maize Zone	1,269	973	1,313	1,692
Western Highlands	902	1,005	1,071	836
Central Highlands	1,856	1,969	2,243	1,991
Marginal Rain Shadow	1,015	632	1,488	1,434
Overall Sample	**1,164**	**1,079**	**1,298**	**1,371**

Further analysis of milk productivity by wealth quintiles shows that the level of productivity is lowest for the least wealthy households, while that of the wealthiest households more than doubles productivity for the least wealthy households (Table 28).

Table 28: Cow Milk Median Productivity (liters/cow) by Wealth Quintile, 1997-2007

Wealth quintile	1997	2000	2004	2007
Lowest	838	711	834	765
2	919	895	831	1,060
3	1,094	898	1,231	1,220
4	1,203	1,078	1,509	1,530
Highest	1,451	1,535	1,646	1,878
Overall Sample	**1,164**	**1,079**	**1,298**	**1,371**

3.8.1 Factors driving productivity growth in dairy

Households' increased investment in the dairy enterprise is the major reason for increased milk productivity. Table 29 shows that the proportion of households growing fodder increased from 16% in 1997 to 53% in 2007. The Central and Western highlands regions have the largest proportions of households growing fodder; from 40% in 1997 to 94% in 2007 and from 19% in 1997 to 92% in 2007, respectively. Fodder growers also increased substantially in Marginal rain shadow (3% in 1997 to 65% in 2007) and Eastern lowlands (5% in 1997 to 54% in 2007). The proportion of fodder growers did not rise as much in High potential maize zone (16% in 1997 to 44% in 2007) and Western transitional (10% in 1997 to 43% in 2007). Fodder growing is least popular in the Coastal and Western lowlands.

The likely reason for more popularity of fodder growing in Central and Western highlands than in the High potential maize zone, even though dairy is an equally important enterprise in the High potential maize zone, is that household land holdings are smaller in the Central and Western highland zones, limiting open pasture grazing. We, therefore, see by these trends a tendency towards more intensive dairy production. But how much land do the households allocate to fodder?

Table 29: Proportion (%) of households growing fodder[4]

Zone	1997	2000	2004	2007
Coastal Lowlands	-	-	1	-
Eastern Lowlands	5	48	54	54
Western Lowlands	-	3	6	5
Western Transitional	10	18	26	43
High Potential Maize Zone	16	16	33	44
Western Highlands	19	74	81	92
Central Highlands	40	88	94	94
Marginal Rain Shadow	3	19	35	65
Overall Sample	**16**	**37**	**46**	**53**

[4] Note: Fodder includes nappier/elephant grass, oats, lucerne, maize meant for fodder

Table 30 shows highly variable mean land area per household allocated to fodder by fodder growers. The mean land allocated to fodder generally decreased from 0.5 acre in 1997 to 0.4 acre in 2004, but later rose to 0.6 acre in 2007. The largest increase in land area allocated to fodder occurred between 2004 and 2007, reflecting on the increase in the overall milk productivity between 2004 and 2007, which again was the highest of the three inter-year periods.

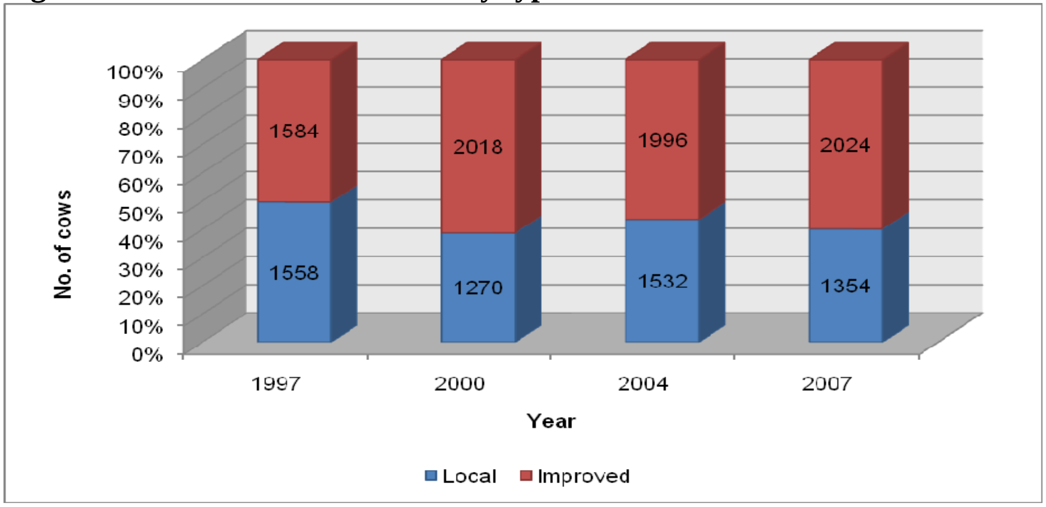
Regionally, the High potential maize zone and Marginal rain shadow have the largest mean land area allocated to fodder. However, area per household allocated to fodder declined in the High potential maize zone from 0.88 acre in 1997 to 0.80 acre in 2007 and in the Marginal rain shadow from 1 acre in 1997 to 0.89 acre in 2007. The decline is also seen in the Western highlands from 0.39 acre in 1997 to 0.23 acre in 2007. The Central highlands and Eastern lowlands, on the other hand, saw the mean acreage under fodder rise from 0.37 acre in 1997 to 0.43 acre in 2007 and 0.9 acre in 1997 to 1.32 acre in 2007, respectively. While the increase in land area allocated to fodder in Central highlands can be reflected in increase in milk productivity, the same cannot be said of Eastern lowlands, where milk productivity has remained about the same over the panel period.

Table 30: Area (acre/hh) allocated to fodder by fodder growing households.

Zone	1997	2000	2004	2007
Coastal Lowlands	-	-	0.06	-
Eastern Lowlands	0.90	0.42	0.49	1.32
Western Lowlands	-	0.41	0.12	0.46
Western Transitional	0.32	0.54	0.24	0.45
High Potential Maize Zone	0.88	0.70	0.65	0.80
Western Highlands	0.39	0.31	0.28	0.23
Central Highlands	0.37	0.40	0.31	0.43
Marginal Rain Shadow	1.00	0.89	0.61	0.89
Overall Sample	**0.53**	**0.44**	**0.39**	**0.60**

A part from feed and animal husbandry, on-farm milk productivity is also a function of genetic make-up of an animal. Figure 2 presents a chart showing the total number of cows by type reported owned in the overall sample. We see an increase in the number of improved cows from 1584 in 1997 to 2024 in 2007. At the same time, the number of indigenous (local) cows declined from 1558 in 1997 to 1354 in 2007. The trends show that households are generally moving away from keeping local cows to keeping improved cows. This again reflects on the general increase milk productivity.

Figure 2: Number of cows owned by type



To give a clearer picture of the regional patterns in cow types kept, we present in Table 31 the proportion of cow-owning households keeping improved cows. This proportion generally consistently increases from 62% in 1997, 65% in 2000 to 70% in 2004, but declines slightly to 66% in 2007. The proportion remains high in the Central highlands (between 98% and 100%) and High potential maize zone (between 83% and 88%) over the decade. Western highlands and Marginal rain shadow register impressive increases in the proportion of households keeping improved cows; from 39% in 1997 to 75% in 2007 and from 67% in 1997 to 81% in 2007, respectively. There is also an impressive increase in this proportion in the Coastal lowlands from 0% in 1997 to 25%. Keeping improved cows, on the other hand, seems to be a rarity in the Western lowlands, with the proportion of households rising from 3% in 1997 to 5% in 2004, and then drastically declines to only 1% in 2007. It is in this region where milk productivity is lowest.

Table 31: Proportion (%) of cow-owning households keeping improved cows[5]

Zone	1997	2000	2004	2007
Coastal Lowlands	0	0	26	25
Eastern Lowlands	34	32	54	42
Western Lowlands	3	4	5	1
Western Transitional	32	35	37	34
High Potential Maize Zone	84	83	88	85
Western Highlands	39	71	72	75
Central Highlands	98	98	100	99
Marginal Rain Shadow	67	77	83	81
Overall Sample	**62**	**65**	**70**	**66**

Farmers can only invest their time and money in dairy production if they are assured of making profits thereof. Price levels are an incentive to farmers to invest in an enterprise. Trends in the

[5] Improved cow refers to pure grade cow or a cow cross-bred between pure grade and indigenous type

dairy productivity and investment in productivity enhancing inputs can be explained by trends in producer milk prices. Table 32 shows that producer price per litre of milk generally rose from Ksh 14 in 1997 to Ksh 19 in 2007. In the highest milk producing regions of Central highlands and High potential maize zones, the price per litre of milk rose from Ksh 11 and Ksh 12 respectively in 1997 to Ksh 16 in 2007. Milk price equally increased from Ksh 18/litre to Ksh 23/litre between 1997 and 2007 in the Western highlands, and from Ksh 14 to Ksh 21 between the same period in the Western transitional zone. It is worth noting that milk prices remained high in the lowlands (between Ksh 21/litre and Ksh 34/litre) between 2000 and 2007. The lowest milk prices were recorded in the Marginal rain shadow, rising from Ksh 12/litre in 1997 to Ksh 14/litre in 2000 and then drops back to Ksh 12/litre in 2004 to settle at Ksh 13/litre in 2007. These trends, showing marginal milk price increases could have acted as incentives for farmers to invest in dairy production. However, the real prices calculated using Gross Domestic Product (GDP) deflator shows that the real producer prices have declined from Ksh. 25 per litre to Ksh. 19 per litre.

Table 32: Producers' Milk Prices (Ksh. /litre)

Zone	**Nominal Price (ksh/litre)**				**Real price in Ksh/litre (Using GDP deflator)**			
	1997	**2000**	**2004**	**2007**	**1997**	**2000**	**2004**	**2007**
Coastal Lowlands	9	34	21	23	16	50	26	23
Eastern Lowlands	15	24	25	30	26	35	31	30
Western Lowlands	20	21	25	24	35	31	31	24
Western Transitional	14	21	21	21	25	31	26	21
High Potential Maize Zone	12	16	15	16	21	23	19	16
Western Highlands	18	21	22	23	32	31	27	23
Central Highlands	11	15	15	16	19	22	19	16
Marginal Rain Shadow	12	14	12	13	21	20	15	13
All zones	**14**	**18**	**18**	**19**	**25**	**26**	**22**	**19**

4 CROSS-CUTTING FACTORS DRIVING PRODUCTIVITY GROWTH

4.1 Improved Access to markets

4.1.1 Reduced distances to motorable road

Although distance to the market is a key issue in productivity, quality of roads is a critical factor in determining access to markets, both for inputs and outputs, and merits consideration in agricultural productivity debate. Distances to motorable and tarmac roads are presented in Table 33). There is a significant decline in distances to a motorable road from an average of 1 km in 1997 to 2004 to 0.5 km in 2007. The reduction in distances to motorable road could be associated with investments in maintenance of feeder roads (graders, bridges, culvert, murram) in the rural areas following the introduction of the Constituency Development Fund (CDF). This is a decentralised fund introduced in 2003 where all the 210 constituencies are allocated 2.5% of the total government revenue. Analysis show that in 2005, road related projects at the constituency level accounted for 11% of the total constituency budget (authors' calculation from www.cdf.go.ke).

Distances to tarmac roads, however, did not change during the panel period. Households have to cover longer distances to reach tarmac roads. Households in Central highlands and Western lowlands have the shortest distances, between 5km and 6km, away from tarmac roads. Households in the Western high lands, Western transitional and High potential maize zone regions have distances to tarmac roads ranging between 7km and 8km. The most disadvantaged regions in terms of distance to the tarmac road are Marginal rain shadow and Eastern Lowlands, where households cover between 11km and 16km to reach tarmac roads.

Table 33: Distance (km) to Motorable and Tarmac roads

	Distance to motorable road				Distance to tarmac road			
Zone	**1997**	**2000**	**2004**	**2007**	**1997**	**2000**	**2004**	**2007**
Coastal Lowlands	1.5	1.6	1.6	1.0	8.9	10.2	9.8	9.2
Eastern Lowlands	1.5	1.1	2.3	0.5	14.9	11.9	11.9	12.4
Western Lowlands	2.1	1.1	1.1	0.6	5.9	6.0	6.4	6.5
Western Transitional	0.5	0.7	0.8	0.4	7.2	8.7	8.0	8.4
High Potential Maize Zone	0.8	1.8	0.6	0.6	8.2	6.8	6.5	6.6
Western Highlands	1.5	1.2	1.2	0.5	8.2	7.3	7.9	7.4
Central Highlands	0.5	0.7	0.7	0.2	5.6	5.2	5.5	5.4
Marginal Rain Shadow	2.2	3.2	2.0	1.0	11.4	15.7	13.5	12.4
Overall sample	**1.1**	**1.3**	**1.1**	**0.5**	**8.2**	**7.7**	**7.6**	**7.6**

4.2 Improved Access to Extension and Financial Services

Extension and financial services are among some of the important factors determining agricultural productivity performance. Sustained access to these services by farmers is critical in ensuring improved agricultural productivity. Over the panel period, information on households' proximity to sources of extension and veterinary services were gathered. Households' access to credit (agricultural and non-agricultural) was also explored. Summary of the results are presented in the following sub-sections.

4.2.1 Reduced distances to extension services

There exists a general consensus that if properly designed and implemented, extension services improve agricultural productivity (Romani, 2003; Evenson and Mwabu, 1998). Agricultural extension services provide farmers with important information, such as patterns in crop and livestock prices, new and existing technologies, crop and livestock management, and marketing. Exposure to such information enhances farmers' ability to optimize use of the scarce resources at their disposal. Awareness of existing technologies generates effective demand by providing a critical signal to input distribution systems (Davidson *et al*, 2001). Extension systems and input distribution systems are, therefore, mutually reinforcing in their contribution to agricultural productivity (Muyanga *et al* (2006).

Proximity to extension service providers is critical in access to extension services. Table 34 presents mean distances between farmers' homesteads to where they can access both crops and livestock advisory services, either private or public, over the panel period.

Table 34: Distance to crop and veterinary extension service provider

	Distance to source of crops extension service				Distance to source of veterinary service			
Zone	**1997**	**2000**	**2004**	**2007**	**1997**	**2000**	**2004**	**2007**
Coastal Lowlands	9.8	12.4	12.3	5.8	9.0	12.2	10.9	4.7
Eastern Lowlands	5.5	4.6	6.0	5.5	5.2	3.9	4.8	3.7
Western Lowlands	6.7	7.7	6.6	5.9	6.3	2.5	5.6	5.3
Western Transitional	5.4	4.6	4.5	4.3	4.6	4.3	3.7	3.8
High Potential Maize Zone	5.4	5.9	5.6	5.6	5.1	4.5	4.6	5.3
Western Highlands	5.3	5.2	4.8	3.8	3.5	3.0	3.4	2.8
Central Highlands	3.6	3.0	2.2	2.3	2.9	2.4	1.7	2.0
Marginal Rain Shadow	2.8	2.0	3.0	2.3	4.2	2.8	3.0	4.5
National sample	**5.4**	**5.5**	**5.2**	**4.6**	**4.8**	**4.0**	**4.3**	**4.0**

Households' proximity to crop extension service providers improved from a distance of 5.4 km in 1997 to 4.8km in 2007, while that to veterinary extension service providers improved from 4.8km in 1997 to 4km in 2007. The reduction in distances to extension service providers is seen in all the regions. Households closer to extension service providers used high yielding technologies and realized higher yields than households far away from such providers. While other factors most likely contribute to these relationships, the proximity to extension services does appear to be correlated with small farmers' uptake of productivity enhancing technologies (Muyanga *et al*, 2006).

However, the distances vary in length across the regions. Households in Central highlands and Marginal rain shadow have the shortest distances to both crop and veterinary extension services.

Households in the Lowlands, on the other hand, are the farthest from extension services, with Coastal lowlands' households as far as 5.8km and 4.7km from crops and veterinary extension services respectively in 2007. It is noteworthy that the Lowlands, where distances to extension services are longest, are associated with lower maize productivity. Muyanga *et al* (2006) argue that this can be interpreted to mean that either absence of extension services at close proximity to households causes low agricultural productivity or that agricultural extension agents are not keen to serve regions with low agricultural productivity. The former argument seems plausible since it is the Lowlands which are associated with lower adoption levels of fertilizer and high yielding maize seed varieties compared to other regions (except Marginal rain shadow).

Improvement in distances to extension services could be attributed to conglomeration of interventions by many stakeholders such as the Government through the National Agricultural Livestock Extension Program (NALEP), Private commercial companies (promotion, advertisement, field trials, and business fairs), Non-governmental Organisations (NGOs) among other players.

4.2.2 Access to Financial Services

Although agricultural extension service is necessary to raise the awareness of farmers of existing and new technologies, it is not sufficient in itself to raise agricultural productivity due to many factors that influence productivity. The panel data reveals a considerable widespread and increasing adoption of fertilizers and high yielding maize varieties. Nevertheless, it is probably the quantities and types of fertilizer and quality of seeds available to the farmers, rather than just awareness by the farmers of their existence, that have the biggest impact on productivity. Consequently, availability of working capital to the farmers to acquire adequate productivity enhancing inputs is of critical importance in strategies aimed at improving agricultural productivity. Rural financial services, therefore, are an important component in the set of services necessary for agricultural productivity growth. Using a Levene test of variance, Kibaara, (2006) demonstrated that farmers who accessed agricultural credit recorded higher level of maize productivity than those that did not.

The proportion of households seeking general credit increased from 46% in 1997 to 53% in 2007. Similarly, the proportion of households seeking agricultural credit rose from 29% in 1997 to 37% in 2007. Table 35 shows that the proportion of households receiving agricultural credit increased from 26% in 1997 to 30% in 2000. This proportion declined to 26% in 2004, but rose again to 33% in 2007. The trend reveals an increasing, albeit slowly, access to agricultural credit among rural households in Kenya.

Table 35: Proportion of households that received agricultural credit

Zone	1997	2000	2004	2007
Coastal Lowlands	5.3	1.3	1.3	9.3
Eastern Lowlands	17.2	8.3	1.4	17.2
Western Lowlands	5.2	12.4	7.8	19.6
Western Transitional	28.4	46.6	39.9	47.3
High Potential Maize Zone	15.6	15.9	13.3	19.1
Western Highlands	34.9	41.9	36.4	42.6
Central Highlands	60.7	65.3	64.0	65.3
Marginal Rain Shadow	8.1	24.3	8.1	18.9
National sample	**25.7**	**29.6**	**25.5**	**32.8**

Agricultural credit appears to be more accessible in the more agriculturally productive regions of Central and Western highlands, Western transitional and High potential maize zone, than in less agriculturally productive regions; the Lowlands and Marginal rain shadow. In the Central Highlands, the proportion of households that received agricultural credit over the decade remained in the range of 61%-65%, while in the Western highlands this proportion ranged from 35% to 43%. In the Western transitional zone, the proportion of households receiving agricultural credit rose form 28% in 1997 to 47% in 2007, while in the High potential maize zone agricultural credit recipients rose form 13% to 19% between 1997 and 2007. In the Coastal lowlands, the proportion of households receiving agricultural credit declined from 5% in 1997 to 1% in 2004, but rose to 9% in 2007. It is in this zone where agricultural credit is least accessible. It is observed that the regions with higher access to agricultural credit are those in which industrial crops such as tea, coffee, and sugar cane are produced. Some of these crops have organised inputs credit schemes.

Close to 50% of the households received agricultural credit from the commodity based credit providers such as KTDA and sugar companies (Table 36). The informal money lenders (self help groups, shylocks, community associations, merry go round, village 'banks') surpasses the cooperatives and the banks in provision of informal agricultural related credit.

Table 36: Percentage shares of sources of agricultural credit

Sources of Agricultural credit	1997	2000	2004	2007
Commodity Based credit providers (KTDA, sugar company, NIB)	13.5	55.8	62.2	48.7
Informal money lenders	16.5	10.6	8.6	19.8
Traders/Input stockists	10.4	6.2	3.7	10.5
Cooperatives/SACCOs	55.8	25.9	21.9	10.3
Agricultural Finance Corporation	3.0	0.5	1.7	5.2
MFI/NGO	-	0.5	0.6	3.1
Commercial banks	0.8	0.5	1.2	2.5

The traders or input stockist have continued to provide credit to farmers. Results reveal a gloomy trend in provision of credit by cooperatives, such as coffee cooperatives, where the credit market share has declined from 55% in 1997 to only 10% in 2007. This is one of the contributing factors to the poor performance of the coffee sub sector.

Provision of Agricultural credit by AFC to the farmers in this sample has slightly increased from 0.5% in 2000 to 5.5%. This is associated with the revival of AFC following revamp of Ksh. 1.3 billion for the period 2003-2007. This enabled AFC to resume the seasonal crop credit and development loans. In addition, AFC is implementing the wholesale lending approach. However, AFC's contribution to smallholder farmers is still very insignificant. Trends also show more financial stakeholders increasing their participation in the credit landscape. In 1997, there was no MFI/NGO that gave credit to farmers in this sample, however by 2007; the MFIs accessed credit to 3.1% sampled households. In 1997, the banks provided agricultural credit to less than 1% of the sampled households before increasing to 2.5% in 2007.

5 SIGNIFICANT DETERMINANTS OF AGRICULTURAL PRODUCTIVITY

This study estimates frontier production and yield response functions for different maize zones using a unique panel data on Kenyan households. The estimates from this analysis will provide indicators of the marginal productivity impact of fertilizer for maize. The results will help identify the regional, village, and household characteristics associated with the use of improved maize production technologies among smallholders in the region. The study derives technical efficiency measures for each farm from the estimated production frontier function, and assesses the potential for increasing the maize yield response of fertilizer. Based on this analysis, it is possible to assess whether fertilizer use in various regions and production systems is generally profitable, whether low fertilizer use rates in some areas reflects input or credit market failures, inefficient use of fertilizer, or a lack of profitability even when smallholders producing maize and using fertilizer relatively efficiently.

Robust panel data methods are utilized to control for farm-specific and household specific unobserved heterogeneity. This is an important advantage in survey analysis of yield response where so many relevant factors to control for are unobserved (e.g., soil quality, plot slope, plot-specific rainfall amounts and dispersion, farmer ability, etc). The whole sample of data used for this work consists of 2754 fields managed by 1091 households out which 769 households use fertilizer for the years 1997, 2000, and 2004.

Stochastic production functions (SPFs) allow for random shocks outside of the farmer's control to affect output. A change in output that is not directly attributable to changes in inputs is attributed to random shocks and technical inefficiency. This variation can be split for shocks due to changes in inputs like fertilizer use and impacts caused by variation in technical efficiency. Technical inefficiency gives an indication of "deviation" between the farmer's observed level of technical efficiency and the farm's unobserved SPF.

$$Y = x'\beta + v - u(z`\gamma) \qquad (1)$$

The independent variables X are those directly influencing output while Z covers the exogenous factors that affect technical inefficiency. The composed error term consists of V-U where V is the usual random noise whose distribution is assumed normal, $N(0,\sigma_v^2)$. The U is technical inefficiency which is a positive, one-sided part of the composed error term whose distribution is often assumed to be half-normal and depends on the exogenous variables Z. The V and U are assumed independent of one another and of X. The U is also assumed independent of Z. The parameters of interest are β and γ which stand for elasticity (if log-log form is used) and effect of Z on inefficiency respectively.

Choice of model specification is crucial because the direction or signs and magnitudes of partial effects from the SPF are relevant to policy (Alvarez et al 2006). Yanyan Liu (2006) shows that though most specifications of the SPF provide estimates of partial effects that have similar signs or directions, the magnitudes of these parameters might differ for different specifications therefore leading to varying policy implications. Functional forms are selected for their simplicity of estimation, theoretical consistency, and their flexibility. The most common functional forms are the Cobb-Douglas and the Flexible Translog for the SPF. The latter form which nests the Cobb-Douglas specification is shown below:

$$\ln y_{it} = \alpha_0 + \sum_{j=1}^{k} \alpha_j \ln x_{ijt} + \frac{1}{2}\sum_{j=1}^{k}\sum_{k=1}^{k} \alpha_{jk} \ln x_{ijt} \ln x_{ikt} + v_{it} - u_{it} \qquad (2)$$

The variables are explained above and U is dependent on exogenous variables Z. The Cobb Douglas specification does not have the third term (interactive) above and has the advantage of less variables (leading to parsimony) and elasticities can be read off directly.

Whichever functional form is chosen, estimation follows either of two approaches. The oldest and simpler method is a two stage estimation procedure. First, the SPF is estimated by regressing yields on inputs. Then the resulting output is used in the second stage to estimate the inefficiency part by regressing this on exogenous variables that affect farm productivity. This gives biased estimates since the first stage estimation has omitted variables that might be correlated with the input variables (correlation between x and z) or the inefficiency is measured with error which is then correlated with Z in the second stage (Wang and Schmidt 2003). The other approach is the one-step systems approach which uses all the information and avoids bias. This study uses the Battese and Coelli (1992) one-step estimation using pooled and panel data. Battese and Coelli (1988) suggest that each firm's technical efficiency be measured by TE=exp($-u_i$) when using panel methods with variables in log form. Time varying or invariant methods have recently become of interest with a number of researchers modeling changes in inefficiency over time. This is done by either assuming that technology has not been changing and so any significant changes relate to efficiency changes or by testing for technological changes and then disentangling this from inefficiency changes. The Battesse and Coelli (1992), hereafter B&C, approach test for significance of η in estimation of time varying inefficiency using the formula $TE = U\exp(-\eta(t-T))$ where U= exp($-u_i$), T is the number of years for the panel, and t is the observation number for each individual. If η is not significant then inefficiency is invariant as $TE = U$. If η is negative then TE increases with time and if this is positive then TE is decreasing over time. Other formulations of time varying inefficiency exist (Schmidt et al 2002) but this study will use the above method.

5.1 Data

For this analysis the data was organized by field with each household having one or more fields under a pure-stand crop or a mixed crop in the same field. Of these only 1091 households had adequate data for our analysis. There are 769 households out of the 1091 that used fertilizer on their fields. It is important to note that a household can have more than one field planted with maize. Therefore the total number of household is less than the number of fields in the sample of household.

To focus on fields where maize is the main crop, we drop fields with more than three crops[6]. This yields 2574 fields for all the three survey years, 15 percent of which are pure stand maize

[6] Fields with more than three mixed crops imply maize is getting relatively less emphasis

fields, 55 percent have two mixed crops and the rest three crops per field. Of the 2574 fields run by 1091 households, fertilizer is applied to 1716 fields.

Due to the large proportion of missing data for marginal rain shadow and coastal lowlands zones, these zones have been dropped from the analysis. The remaining six zones have been reclassified into four main zones with fairly similar characteristics as depicted in Table 37.

Table 37: Re-Classification of AEZs

Zone 1		Zone 2		Zone 3		Zone 4	
District	AEZ 3 & 4	District	AEZ 5 & 7	District	AEZ 6	District	AEZ 8
Taita Taveta Kitui Machakos Makueni Mwingi Kisumu Siaya	Eastern Lowlands Western Lowlands	Kisii Bungoma Kakamega Vihiga	Western Transitional Western Highlands	Bungoma Kakamega Bomet Nakuru Narok Trans Nzoia Uasin Gishu	HPMZ	Meru Muranga Nyeri	Central Highlands

Zone 3 is the high potential maize zone (HPMZ) covering areas where most of the country's maize comes from. Zone 4 lies on the highlands is generally associated with the coffee cooperative movement and its fertilizer use has been influenced by the infrastructure laid by this organizations (Ariga and Jayne, 2005) and has one of the highest fertilizer rates in the country (comparable only to zone 3).

Each field has data that includes field size in acres, production for each crop, amount of fertilizer consumed for each field, amount of seed planted for each crop, type of maize seed (hybrid and non-hybrid). Hybrid seed has higher potential productivity and is more expensive than non-hybrid or what is called local or traditional seed in the survey. A hybrid dummy is used to indicate that for the particular field hybrid seed was used. Data is also available on household demographics on age, years of education, gender, employment and on infrastructure like distance to extension service and to fertilizer sellers.

Since about 85% of the maize fields are mixed crop fields, to account for the relative proportions of the different crops we get a representative estimate of yield or production by creating a yield index for each field. The yield index was estimated using the following formula: $\sum p_i \ (q_i / p_*)$ where p_i and q_i are the prices and quantities of crops mixed with maize in the field and p_* is the price of maize. This provides a measure of yield encompassing all crops in the fields in maize quantity equivalents. This is simply multiplying each crop's quantity by the relative price and summing the products. The relative price is the ratio of the price of each crop and that of maize. Analogously, we estimate seed use per field by creating an index for field seed consumption using price of seed maize as a weight in this case.

However, the labor data is incomplete for some households (no data for year 2000) and we substitute the adult equivalent per acre cropped as a proxy for labor input. The household adult equivalent[7] for each field is estimated by dividing the household adult equivalent by total cropped area to get per acre equivalent. We also use a dummy indicating tractor or ox use for land preparation as opposed to manual preparation using a hand-held hoe.

We address the problem of unobserved time-constant factors using fixed-effects panel models. In the models using pooled cross-sectional data, agro-ecological zone dummies are included to partially capture these differences since farmers in the same zone face fairly similar environments. In addition village level rainfall variables are added to capture stress in particular areas. This variable is estimated by the fraction of 20-day periods with less than 40mm of rainfall during the main season.

Table 38 gives summary statistics of some of the variables we use in this study for fertilizer users and fertilizer non-users. Average yields are 1218 kilograms per acre or approximately 13.5 bags of 90-kilograms each for fertilizer users, a common measure for maize and other crop output in Kenya. Fertilizer and seed rates per acres are 58 and 25[8] kilograms per acre respectively. For non-users of fertilizer, yields are comparably lower at 720 kilograms and seed rates at 18 kilograms/acre. This is 8 bags an acre which is about 60 percent of yields for users.

For fertilizer users, the average family size consists of 7 members with field sizes of approximately 1.5 acres and household productive assets worth KShs 143,000 (slightly more than US$2,000 at current exchange rates). For non-users of fertilizer these statistics are 7, 1.3, and Kshs 111,700 respectively. The average age of the head of household is 51 years with about 7 years of education (6 years for non-users). The average distance to a fertilizer seller is 3.1 kilometers and to an extension service office is 4.9 kilometers from the farm (these are 7.5 kilometers and 5.8 kilometers respectively for non-users). The average rainfall for the main season was 723 mm for fertilizer users and 664mm for non-users of fertilizer.

[7] The household adult equivalent was divided by the total household area under crops and used as a proxy for labor since labor data is missing for most households.

[8] Recommended seed rates for hybrid seed maize is 10 kilograms per acre. The rate indicated here is an index of all crops in the field as explained above.

Table 38: Summary Statistics For Variables used in the Analysis[9] (Years 1997, 2000, and 2004)

	Fertilized maize fields (n=1,716)		Maize fields with no fertilization (n=858)	
Variable	Mean	Std Dev	Mean	Std Dev
Yield Index* (kilograms/acre)	1217.80	960.28	720.13	883.13
Fertilizer rate Index (Kilograms/acre)	58.41	43.28	0.00	0.00
Seed rate Index (kilograms/acre)	25.18	27.48	18.87	22.15
Household Size (#)	6.87	2.89	7.16	3.08
Field size(acres)	1.54	1.63	1.34	1.25
Fraction of 20-day periods with rain <40mm - Main season	0.19	0.21	0.18	0.22
Rainfall for main Season (mm)	723.56	249.72	664.76	220.95
Productive Assets (Shillings/acre)	143,347	440,580	111,735	281,640
Distance to Fertilizer Seller (Kilometers)	3.09	3.89	7.54	9.16
Distance to Extension Service (Kilometers)	4.85	4.01	5.83	4.4
Age of Household Head (years)	51.33	13.05	51.25	12.75
Education of Household head (Years)	7.25	5.06	5.81	4.09
Household Highest Education Level (Years)	10.05	5.13	8.25	4.41
Number of crops in Field	2.17	0.64	2.12	0.68

5.2 Stochastic Production Frontier

For the production frontier, the dependent variable is the logarithm of the yield index and the explanatory variables are the logs of levels of fertilizer consumption, household adult equivalent, seed used, and the size of the fields and their interactions, a dummy for land preparation technique (tractor vs. ox/hoe), dummy for whether hybrid was used, and dummy for mixed crop fields versus pure stands. Agro-ecological zone dummies and year dummies are also used to capture differences across regions and year effects. We also include rainfall stress variables for main season since the analysis is done on main season data. Since both dependent and independent variables are in logarithmic form, the coefficients can be directly interpreted as elasticities for the Cobb Douglas specification. However, for the translog formulation these have to be estimated using the cross-product terms and these estimates are not unique as they vary depending on what values of variables are used.

5.2.1 Model specification

Before we estimate the parameters of interest we embark on deciding what variables to use for our regressions. There are a number of reasons for this. First, too many variables will draw on the degrees of freedom particularly if the number of observations is not large enough. Second,

[9] This table consists of fields with maize as main crop (mixed fields with less than four crops)

regressions involving maximum likelihood can become very complicated when there is over-parameterization. The key to reliable regressions is flexibility and parsimony. Taking this into account, we select our variables taking advantage of simple approaches as much as we can (using OLS with the full set of variables followed by MLE once we have fewer variables as explained below).

We start with the production frontier from equation (2) in Section 5.0 with the full set of variables except those of the inefficiency part. First, using the F-test based on OLS estimates we test joint significance of variables and drop those that fail the test. This gives a smaller subset of the above variables and their interactions. However, the problem with OLS is that if the variables are correlated with the error term then we have inconsistent estimates. This potential problem is counter-checked in out third step below to make sure that this is the right step using an approach similar to Liu (2006). The second step uses one-step MLE regression of the production function with the reduced set of variables plus the inefficiency equation with full set of the inefficiency variables. Using LR and Wald tests we drop jointly insignificant variables for the inefficiency component. Our last regression is to confirm that the variables we dropped in the first step are indeed insignificant. We run a one-step MLE using the original full set of variables for the production function and the reduced set of variables for the inefficiency equation. We then use LR and Wald statistics to re-test the joint significance of the variables dropped in the first step. A LR ratio test of the unrestricted model (with original variables we started with) against the restricted model (the final reduced set) has a p-value of 0.3545 (and chi-squared statistic of 3.53). This means that we fail to reject the null that the dropped variables are equal to zero in both cases. Therefore the dropped variables need not be included in our modeling.

5.2.2 Panel Regression results

We assume that there is no technical change due to the short panel period for this data. Therefore, any changes in this period will be attributed to changes in inputs, technical inefficiency, and idiosyncratic random shocks. We use two approaches in our panel analysis. First we apply the B & C model using maximum likelihood to estimate both the stochastic and inefficiency equations simultaneously. We compare this with two-step approaches using Fixed Effects (FE) and Random Effects (RE) regression in the first step for the production function then follow this with the second step to recover the inefficiency estimates using the residuals from the earlier step.

The FE regression in particular assumes that individual effects are correlated with the exogenous variables and this makes intuitive sense considering that unique management characteristics or farm-specific conditions have an impact on decisions impacting on yields. The usefulness of panel data is the ability to use approaches like that of FE to eliminate these unobservable effects. We tested RE against FE using both the translog and Cobb Douglas models using the Hausman, LR and Wald tests and rejected the RE model in favor of FE. Since our model selection rejects RE in favor of FE, this is suggestive that these effects are not random but are correlated with exogenous variables so we need to de-mean these effects away so that we can get consistent estimates. The RE is preferred if there is a systematic difference between the estimates from the two regressions (i.e. if the individual effects are exogenous). In this case the tests indicate that they are not.

The estimates of elasticities from these regressions are given in Table 39 below. These elasticities are comparable to those from the pooled regression (not included here). The signs on the coefficients are similar and the magnitudes not that different. Just like in the pooled regressions, estimates from the translog model are slightly bigger than those form Cobb Douglas model. The translog specifications using B&C, FE and RE have elasticity estimates that have the same sign and the magnitudes are very close. The same relationship exists between for the Cobb Douglas approach using B&C, FE and RE.

Table 39: Elasticities for the Panel Regressions

Model	Specification	Fertilizer Rate	Seed Rate	Field Size	Adult equivalent	Assets	Stress	Hybrid
B & C	Translog	0.282[a]	0.295[a]	-0.361[a]	-0.071	0.049	-0.023	0.192
FE	Translog	0.246[a]	0.374[a]	-0.366	-0.016	0.058	0.002	0.146
RE	Translog	0.283[a]	0.302[a]	-0.376[a]	-0.081	0.047	-0.029	0.172
B & C	Cobb Douglas	0.242[a]	0.205[a]	-0.185[a]	-0.075[a]	0.061[a]	-0.012[a]	0.079
FE	Cobb Douglas	0.193[a]	0.244[a]	-0.193[a]	-0.007	0.040	-0.001	0.056
RE	Cobb Douglas	0.242[a]	0.208[a]	-0.189[a]	-0.071[a]	0.058[a]	-0.013	0.040

Source: Tegemeo Institute/Egerton University Rural Household Surveys
Note: Superscripts "a" $p<0.01$

Since the data is in logarithmic form, the interpretation of parameters is straightforward. A 10 percent increase in fertilizer use will raise the yields per acre by approximately 2.82 percent, using the B&C model results. The economic ramifications are explained in the next table: for instance raising fertilizer use by about 5 kilograms per acre cropped will raise maize yields per acre by 34 kilograms in Western Highland zone. For fertilizer non-users, a test of change in technical efficiency over this period using the B&C model is rejected for this sub-sample that does not use fertilizer. Therefore, technical efficiency did not change for non-users over this period. In addition the stress and hybrid effects are more significant with larger magnitudes when compared to users of fertilizer. A possible explanation is that there is potential for hybrid seeds to raise yields in such areas if stress were minimized.

Using the translog fertilizer elasticity for the B & C model we estimate the following VCRs for the four zones (Table 4) for users of fertilizer. Again we need to interpret these results with caution as explained in Section 5. Fertilizer profitability is highest in zone 3 as fertilizer use per acre increases. With zone 3 being the highest fertilizer consumer per acre (along with zone 4) a case can be made that an additional kilogram of fertilizer is worth less in these zones compared to zones that are using less fertilizer per acre currently.

Like for cross sectional results, there is a trend of decreasing profitability of fertilizer at higher intensities (application rates). This shows that after excluding individual unobserved specific effects using panel data, profitability is higher than what cross sectional analysis shows. This is one of the advantages of using panel rather than cross sectional data.

Table 40: Value Cost Ratios for Fertilizer (Terciles of Users)

		1st Tercile				2nd Tercile				3rd Tercile			
zones		1997	2000	2004	Total	1997	2000	2004	Total	1997	2000	2004	Total
1	N	14	12	33	59	3	1	3	7			3	3
	VCR	4.25	8.79	8.58	7.60	1.59	1.77	3.83	2.58			0.74	0.74
2	N	67	77	57	201	36	47	65	148	29	23	75	127
	VCR	5.31	14.65	4.72	8.72	1.75	3.92	2.48	2.76	1.22	1.91	1.78	1.67
3	N	51	39	34	124	110	88	107	305	68	79	120	267
	VCR	6.21	4.29	9.49	6.51	2.48	2.77	3.85	3.05	1.60	2.02	1.98	1.90
4	N	45	32	42	119	22	16	17	55	40	25	39	104
	VCR	8.86	8.68	9.45	9.02	2.22	4.29	2.44	2.89	1.52	1.95	1.90	1.89
Total	Total	177	160	166	503	171	152	192	515	137	128	236	501
		6.39	10.49	7.66	8.11	2.28	3.28	3.26	2.94	1.50	2.10	1.91	1.85

Source: Tegemeo Institute/Egerton University Rural Household Surveys

5.2.3 Impact of time, hybrid seed, monocrop maize production and land preparation

There is a positive and significant relationship between yield and time dummies for years 2000 and 2004, which implies differences in response rates across the years. A joint test on the year dummies fails to reject that production function intercepts shifted in the period of the survey. Both year dummies are significant and positive indicating yields increased over their 1997 levels (1997 was dropped to avoid multicollinearity). Ariga, Jayne and Nyoro(2005) note that the period preceding the 1997 season had a relatively better crop which depressed maize prices for the 1997 season (leading to poor maize-fertilizer price ratio) that could have contributed to lower fertilizer use in 1997. The periods preceding the 2000 and 2004 cropping seasons had favorable maize-DAP price ratios.

The data shows that yields are generally higher for hybrid seed users compared to non-hybrid users (Table 3). However, the hybrid dummy is insignificant and of mixed sign for the translog models for cross sectional analysis. However, panel data models show insignificant but positive coefficient for hybrid dummy. For non-users of fertilizer, the Cobb Douglas specification gives a positive and significant measure for this estimate, indicating yields increase by .73 percent points for hybrid seed users compared to non-users.

The monocrop dummy is negative for most of the models indicating a decrease in yields when shifting from mixed crop fields to pure stand fields i.e. yields are higher for mixed crop fields than for monocrop fields. This explains the apparent shifting by farmers from monocrop to mixed cropping; fields with three crops increasing from 1997, 2000, to 2004. Land preparation (dummy tractor=1) coefficient is positive and significant for some models but insignificant for others. The pooled regression for Zone 2 is positive and significant for tractor plough and so is the panel regression for B&C and RE.

Zonal dummies in the pooled regression are negative for zone 1 and zone 2 meaning that yields decrease in these zones relative to zone 4 (Central Highlands) which is dropped to avoid multicollinearity. However, compared to Zone 4, Zone 3 (HPMZ) has higher yields per acre.

5.2.4 Weather stress and returns to scale

Stress (fraction of periods with less than 40mm of rainfall) during the main season has negative impact on yields. A 50 percent point increase in stress conditions leads to a 5 to 7.5 percent point reduction in yields per acre depending on the model used (approximately 75-100 kilograms loss of maize i.e. this is equivalent to a loss of 8% reduction in output). Stress estimates are smaller for panel models compared to pooled regression models.

Field size has an insignificant negative relationship on revenues. A 10 percent increase in the size of the fields will lead to 2-3 percent decline in revenues. If this is true, there are two possible explanations for this. First, it may be that smaller fields receive more intense labor input because smaller field size tends to be correlated with increased labor/land ratios. Smaller farms have higher adult equivalent per acre for example compared with bigger size farms. Secondly, smaller fields tend to be more mixed cropped than larger fields and these mixed crops tend to include horticultural crops and other relatively high-value crops. The model results also indicate the importance of productive asset accumulation in raising agricultural productivity. A 10 percent increase in the value of productive assets (KShs 14,000 at the mean) raises output by approximately 1 percent. Since there is a 6-fold difference in asset values between households in the bottom 25% and top 25% of smallholder households ranked by asset levels, this means that, other factors constant, the households in the top asset quartile obtain a level of crop productivity that is 60% greater than households in the bottom asset quartile.

5.2.5 Technical Efficiency

A test of no technical inefficiency is rejected for both pooled and panel regressions. The B & C models reject the null hypothesis of no technical inefficiency and that technical inefficiency does not change over time. To explain the variation of the technical inefficiency, we use the different categories of tenure (own land with or without title and rented), highest household education level, distance to fertilizer seller, distance to extension service locations, gender of household head (female=1), age of household head, whether household earned off-farm income, and total area cultivated as exogenous variables. We used total cropped area as a proxy for total acre owned as data was unavailable for this for the entire year 2000. However, total cultivated area under crops is available from the dataset for the entire period.

A note on the interpretation of the results of the technical inefficiency equation in Appendices 1 and 2 is in order. The variables explain the variation in technical *inefficiency* (the opposite of efficiency), so the interpretation of coefficients has to conform to this. If the sign is negative then this implies that the variable has a negative impact on inefficiency (i.e. a positive effect on efficiency).

The signs of the coefficients on tenure (dummy: renting=1) are marginally significant for the B & C and FE panel models (Annex 3) indicating that households that own their land with or without title are less efficient than renters of land. Tegemeo survey data indicates that rented fields have higher yields and fertilizer doses compared to fields that are owned with or without title. This implies that renters, because they pay a rental fee in order to use the land, have more incentives to intensify input use so as to re-coup the fee and get some profits.

The variable denoting highest number of years of education for the household has a negative and significant coefficient which implies that education increases technical efficiency. Breaking education levels into four categories (none, primary, secondary, post-secondary) has no significant effect on inefficiency hinting at a possibly linear relationship between efficiency and level of education.

The age of household head for the panel regressions has a significant positive effect on inefficiency implying that households with older heads are less efficient (Annex 4 and 5). Though the sign on distance to fertilizer dealer or seller is positive for the panel models indicating increased inefficiency with distance, it is not significant. However, distance to extension services has a positive and significant effect on inefficiency. How far the household is from extension services is negatively correlated with technical efficiency. The sign on the gender of the household head (female=1) is positive and significant for the panel models (Appendix 1 and 2) implying that female-headed households are less efficient in maize production. In general female-headed households have less yields, apply less fertilizer and own fewer assets than households headed by males (this from statistics from Tegemeo/MSU data).

Off-farm income has a positive effect on inefficiency and this might appear puzzling as the expectation is that these resources will be invested in farm activities and hence raise efficiency levels. The obvious inference is that households with off-farm income opportunities are less efficient in maize production which is counterintuitive but this might be explained if off-farm activities tend to compete with management time or some other resources offered by the head of household.

Cropped area is positively related to technical efficiency in maize production. The conclusion is that inefficiency decreases with increase in cropped area.

6.0 Summary of findings from econometric modeling, Conclusions, and Recommendations

Though fertilizer consumption in Kenya is above the average of most of Sub-Saharan African countries (Ariga et al (2006)), the results of this analysis indicate that it is still profitable to increase consumption of fertilizer across the sample area. This study explains some of the reasons why producers are not using optimal amounts of fertilizer despite the additional unit consumed being profitable. For producers from zones with relatively poor rainfall distribution there exist incentives to use less fertilizer and local rather than hybrid seed. Except for Central and Western Highland Zones, non-hybrid seed users face more rainfall stress periods than hybrid seed users. In addition non-hybrid seed users also apply less fertilizer per acre. These insights point at two areas of policy interest, namely R&D to avail hybrid seeds that can withstand some level of stress comparable to local seeds. Alternatively stress can be reduced by provision of irrigation water (as a measure against risk from stress) which might then encourage hybrid seed use and increased fertilizer application. These are all potential public investments that entail substantial investment in physical and financial assets.

The results show that there was a general increase in fertilizer application in 2004 compared to 1997 and also yields increased in the same period. Though empirical results indicate an increase in output, inefficiency remained relatively unchanged across this period with 75 percent of the sample operating below 87 percent efficiency while maximum efficiency for the sample is at 93 percent. This opens up a wide avenue for policy intervention to raise efficiency levels even without introducing new technology. By re-allocating resources in a more optimal way, producers can raise their outputs above current levels. This highlights farmers' need for solid management advice, and the productivity gains that they could achieve from it. Increased fertilizer dose rates can increase outputs and profits for a substantial number of farmers. This may suggest credit and/or management knowledge limitations for many farmers.

The analysis shows that the level of education of the head of household has significant effect on technical efficiency. A graph of estimates of technical efficiency and education levels of head of household shows a direct relationship. This relationship might imply that the more educated heads are able to get information on the right seeds and levels of fertilizer to apply compared to the less educated households. So access to information could be correlated to education level. Distance to extension service has a negative impact on efficiency implying that availability of extension service can raise efficiency for these farmers. This coupled with the finding that higher levels of education improve efficiency, implies that information that leads to better husbandry practices contributes to raising efficiency.

Female-headed households have lower efficiency levels, fewer assets, apply less fertilizer, lower education levels, and generally have lower maize yields compared to male-run households. Studies have shown that financial services are relatively difficult to access for females and this exacerbates the lack of assets. It is important to study credit constraints and possibilities for fertilizer loan programs. The Kenya government is currently providing free primary education but other constraints exist for females that need short to medium run solution.

Irrigation projects especially for vegetable crops that are intercropped with maize can help to smooth incomes for farmers in low potential areas. Since hybrid seed tends to go hand-in-hand with higher fertilizer application and since hybrid seed is associated more with less stressful moisture conditions, water availability is an important consideration in raising productivity for rural producers.

6 SUMMARY OF KEY FINDINGS

The analysis in this report underscores several major findings:

First, the mean land owned per household has declined have the past decade, from 6.1 to 5.8 acres. This is attributed to increasing rural population pressures and land fragmentation. Cultivated land has also declined slightly, especially for area under coffee, Irish potatoes, cabbages, and in some areas, maize. Maize continues to be an important crop among rural farm households and still accounts for over 50 percent of the cultivated land nationwide.

Second, while crop production remains an important source of household income, its significance declined during the panel period. Off–farm income and specifically business activities are increasing in importance. Overall, maize contributes over 30% to full household income. However, results have shown that the contribution of horticulture (fruits and vegetable) and fodder crops (reflecting the rising importance of dairy) is increasing.

Third, while the value of agricultural output per household and per unit of land has risen by 16% and 24%, respectively, over the 1997-2007 period, there are variations in performance by crop. We categorise the commodities under examination into three; Increased productivity, fluctuating productivity and declining productivity.

i. **Increased Productivity**: There is a marked increase in **maize** productivity. The key drivers of this change are; liberalization of the seed industry leading to increased adoption of high-yielding varieties, increase adoption of fertilizer use, reduced distances to agricultural input stockists, and greater density of agricultural input stockists in smallholder farming areas, leading to reduced transaction costs of accessing these inputs. However, among households using fertilizer on maize, mean application rates did not change much over the past decade. **Tea** productivity has slightly increased but mainly in the western region. This is mainly driven by increased adoption of fertilizer and also the quantities of fertilizer applied. **Dairy** has also recorded a marked growth in productivity. Some of the driving factors include; technological improvements leading to adoption of improved breeds, increased smallholder production of fodder crops, and higher farm gate milk prices.

ii. **Declining productivity: Coffee and sugarcane** productivity has declined. From the data, there is a marked decline in fertiliser use. This could be related to the various management challenges facing these two sub-sectors.

iii. **Fluctuating productivity: Cabbages and Irish potatoes** show fluctuation in productivity. Fluctuation in productivity of Irish potatoes could be attributed to challenges in sourcing clean planting material

Other factors that could have contributed to productivity growth are: improved access to extension as a result of increased participation of the private sector, NGOs and Government in supporting extension. There is also a slight increase in the proportion of households that received agricultural credit, albeit only a third of the households. Results show the declining role of cooperative in provision of agricultural credit. However, the commodity-based credit providers such as KTDA and sugar companies) are the highest providers of agricultural credit. There is an increase in participation of the informal money lenders and the input stockist who jointly provide credit to more households than the SACCOS, banks and AFC all combined. Results show an increased participation of AFC, Micro Finance Institutions (MFIs) and commercial banks.

7 POLICY IMPLICATIONS

1. The study shows that increased adoption of fertilizer has contributed to productivity growth in Kenya. The liberalization of the maize seed and fertilizer sub-sectors has lead to increased national consumption of fertilizer and Kenya has been a success case where the private sector has thrived relatively well. The study has shown an increase in the proportion of households that reported fertilizer use in the panel years. Although Kenya has registered high rates of fertilizer adoption, raising the intensity of use still remains a challenge. One of the current factors impeding fertilizer use the high world fertilizer prices in relation to the output price for commodities. The situation is worsened by the current trends in global fertilizer prices where the price of fertilizer such as DAP has increased from US$ 260 in 2007 to US$ 800 in 2008. The rising price of fertilizer and other farm inputs may erode productivity gains and especially in the maize productivity.

   In order to sustain productivity growth and encourage the farmers to increase production and productivity of major enterprises, the farmers will require an improvement in innovative financial services. For example, Through the Private Public Partnership, some of the institutional innovations on agricultural inputs could be up scaled such as the credit guarantee scheme. The most recent example that could be up scaled is the partnership by AGRA, Equity Bank Limited, IFAD, and the Ministry of Agriculture that launched a loan facility of US$ 50 million (Ksh. 3.1 billion) in May 2008 to accelerate access to affordable financing for farmers and agricultural value chain members such as rural input dealers, input wholesalers and importers, grain traders and food processors. The cash guarantee fund of US $ 5 million by AGRA and IFAD would reduce part of the risk of lending by Equity Bank, adding an element of security. The response by farmers and agro-dealers to this initiative has been impressive. By June 2008, US$3 million (Ksh. 1.8 billion) had already been loaned out.

2. Efforts to improve farmers' efficient use of fertilizer and reducing the costs of fertilizer delivery would also help to offset the effects of rising world prices. A forward-looking approach to input market development requires attention to the various determinants of farmers' effective demand for fertilizer. Government can take a number of steps to increase farmers' demand for fertilizer: invest in rural infrastructure, efficient port facilities and standards of commerce to reduce the costs of distribution; scale-up funding of agricultural research to produce seeds that respond to fertilizer; and nurture the development of rural financial systems, market information systems, institutions for contract enforcement, and telecommunications to attract new investments by commodity marketing firms. These "public goods" investments, often considered outside the scope of fertilizer marketing policy, nevertheless strongly affect the demand for fertilizer and hence whether sustainable markets for fertilizer can arise.

3. The study has shown that an estimated 17% of the households did not use inorganic fertilizer during the panel period. One of the impeding factors for none use of fertilizer is the high prices. This indicates that some farmers are still trapped in abject poverty and would need to be 'kick started'. From a welfare and poverty alleviation standpoint, a compelling case can be made to provide free or subsidized inputs for the poor. The debate on "smart subsidies" received new attention after deliberations of the Abuja meeting where African governments agreed to introduce smart subsides for the poor and vulnerable. However, difficulties with effective targeting may stymie the development of sustainable commercial input delivery systems. Above all, the costs can be high, effectively crowding out public funding of other important investments to help reduce poverty and promote agricultural growth. One such program is the National Accelerated Agricultural Input Access Program (NAAIAP), a program by the Kenyan Government targeting 2.5 million farmers owning below 1 hectare of land in 38 districts. The program provides 10kg of seed, 50kg of DAP fertilizer and 50 kg of topdressing fertilizer.

2. The study has also shown the emerging role of input dealers in provision of credit. Currently, there are initiatives of mainstreaming the agro dealers in improving access to agricultural inputs. Though private public partnership, the recent innovation such as the training of agro dealers could be up scaled. The training increase credibility status and increase opportunities for financing from the input manufacturers.

3. Given the existing distribution of landholding sizes within the small farm sectors of in Kenya, land allocation and land settlement will need to be on the policy agenda. Average farm size within the small farm sector is continuing to gradually decline with modest population growth and the closing of the land frontier in many areas. Under existing conditions, the ability of this bottom land quartile to escape from poverty directly through agricultural productivity growth is limited by their constrained access to land and other resources. In the long run, education and dynamic economic growth leading to improved off-farm employment opportunities will offer the best prospects for relieving rural land pressures. However, in the short and medium run, other options will need to be considered.

   Improving access to land among the most land-constrained smallholder households would be a seemingly effective way to reduce poverty. Statistical evidence in Jayne et al (2003) indicates that even a very small incremental addition to land for small farms is associated with a large relative rise in income. Yet improving land access for smallholders is fraught with difficulties. Expropriating land reform is politically difficult, expensive, and subject to rent-seeking, and "market-assisted" or "community-based" approaches have met with very little success to date. Hence, perhaps the most promising scope for policy discussions on agricultural and rural poverty entail "land settlement" – how to provide incentives for rural families to re-locate to sparsely populated but productive land and provide a reasonable chance for them to become viable economic and social units.

Basic public investments to encourage the productive utilization of currently under-utilized areas with good agro-ecological potential also has a potential in Kenya to redress the current land constraints faced by many of its impoverished and isolated rural smallholder households. The basic investments include feeder roads linked to trunk highways, health care facilities, schools, electrification, irrigation and tax incentives for agribusiness investment. A policy environment conducive to business development can also attract new capital into newly settled areas with good agricultural potential.

4. Coffee Sector

The study has shown a decline in productivity for the once vibrant coffee sector which produced over 130,000 tonnes per year in late 1980s. Today, the country only produces 53,000 tonnes. However, the sector has faced many challenges related to world prices in the early 1990's, poor management of co-operatives society, high level of indebtness among others.

The Government has intervened to save the industry from an apparent collapse by relieving debts amounting to Ksh. 5.8 million. Other reforms include; reduction in government involvement in coffee marketing and milling while encouraging farmers and private sector participation. The introduction of direct payment system operate alongside the Central Auction system of coffee marketing where farmers were paid more quickly and good quality coffee that fetches high premiums also receives the weekly auction price rather than the yearly average price. To some extent this has avoided the adverse selection problem inherent in the former pool payment system. The establishment of a 'Second Window' and the licensing of the marketing agents have improved prices that are received by the farmers. A Coffee Reform Secretariat was formed in 2005 and one of the mandates was operationalizing the Coffee Development Fund (CoDF). A total of Ksh 100 million was provided to CoDF by the government as seed capital for farm inputs. The Fund started a roll out by giving loans to farmers in January 2007.

In spite of all the reforms, the sector is still underperforming. Although coffee prices have increased from $1.8 per kg in 2000 to $3.0 per kilogram in 2007, the exchange rate has eroded these gains. In addition, farmers have not ripped this benefit as a result of high cost of production. Kenya is among the countries with highest cost of coffee production at $3.5 to $4 per kg. The global average is $1.5 for per kg of clean coffee. Neighboring countries like Ethiopia, Tanzania and Rwanda produce the beans at about $1.2 a kilo. The situation is worsened by transaction costs of handling processing and marketing.

5. Although Irish potatoes could be an important food security crop and especially with escalating prices of maize, little effort has been done to promote access to clean seed. Currently, there are no certified potato seed growers in the country. However, a few farmers buy clean seeds directly from the research stations (KARI –Tigoni). The seeds available in this institution are breeders' seed, which are very costly and their volumes cannot cater for all the farmers. There is need to establish potato seed growers.

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ANNEXES

Annex 1: Mean Value of Crop production at constant price, by zone and gender of household head

[redacted]

Annex 2: Trends in fertilizer and maize seed consumption in Kenya, 1986 – 2004

Cropping season	Quantity of fertilizer (Metric tonnes)	Quantity of seed in (Metric tonnes)
1986/87	227,000	42,209
1987/88	238,000	43,528
1988/89	270,531	42,600
1989/90	237,362	41,400
1990/91	228,215	39,300
1991/92	254,087	42,210
1992/93	232,895	40,305
1993/94	286,519	45,000
1994/95	281,221	43,162
1995/96	289,000	44,670
1996/97	249,000	45,145
1997/98	255,044	44,272
1998/99	264,000	47,017
1999/00	336,000	45,000
2000/01	317,000	49,200
2001/02	329,000	47,769
2002/03	335,009	50,127
2003/04	312,440	49,943
2004/05	351,776	51,000
2005/06	383,285	51,000
2006/07	410,214	51,000
growth 97/07	*65*	*13*

Source: Ministry of Agriculture and FAOSTAT

Annex 3: Percent allocation of CDF to the constituencies in 2004/05

Constituency	Percentage	Constituency	Percentage
Amagoro	11.6	Lugari	8.7
Bahari	2.7	Lurambi	6.1
Baringo Central	9.4	Magarini	13.0
Baringo East	15.2	Makadara	6.3
Bomet	7.0	Malava	9.1
Butere	5.7	Marakwet West	15.4
Central Imenti	24.3	Mathira	2.6
Cherangani	19.0	Matunga	16.7
Dagoreti	38.6	Molo	11.9
Gachoka	14.2	Mosop	11.0
Ganze	12.2	Msambweni	16.9
Gatundu North	7.0	Mukwereini	4.9
Gatundu South	3.5	Mumias	3.4
Gem	11.5	Mutito	2.0
Githunguri	6.1	Mwala	12.9
Igembe	16.8	Mwateta	4.4
Isiolo North	13.9	Mwea	5.6
Kacheliba	11.2	Mwingi North	16.9
Kajiado Central	14.8	Naivasha	11.5
Kajiado North	11.8	Narok South	11.8
Kajiado South	13.9	Ndaragwa	32.9
Kandara	13.9	Nithi	9.6
Kapenguria	14.1	North Mugirango	14.0
Karachuonyo	7.1	Ntonyiri	13.7
Kasarani	28.0	Nyaribari Masaba	26.7
Kasipul	9.1	Ol' Kalau	28.7
Kathiani	11.5	Othaya	2.6
Keiyo North	16.0	Rangwe	8.9
Keiyo South	16.0	Rongai	14.2
Kibwezi	11.7	Runyenjes	18.4
Kieni	0.7	Sabatia	3.8
Kigumo	15.0	Saboti	12.7
Kimilili	8.5	Saikago	8.2
Kinango	11.0	Saku	9.4
Kinangop	22.1	Sigor	7.4
Kipipiri	15.5	Sirisa	13.0
Kisauni	2.1	South Imenti	9.6
Kisumu Townwest	4.6	South Mugirango	11.2
Kitui Central	14.6	Tharaka	3.9

Annex 4: Panel B & C, FE and RE Models (Translog)

Dependent Variable: log(yield)	B&C	FE	RE
INEFFICIENCY EQUATION:			
Dummy: Land tenure (rent=1)	-0.009	-0.006	-0.014
	(0.007)	(0.007)	(0.007)**
ln(age of household head)	0.026	0.010	0.021
	(0.009)***	(0.008)	(0.008)***
ln(education of household head)	-0.001	0.000	-0.000
	(0.001)	(0.001)	(0.001)
Dummy: off-farm income=1	0.002	0.001	0.009
	(0.005)	(0.005)	(0.005)*
ln(distance to fertilizer seller)	0.000	-0.001	0.001
	(0.002)	(0.002)	(0.002)
Gender of Household head	0.023	0.020	0.018
	(0.007)***	(0.007)***	(0.006)***
ln(cropped land area)	-0.011	-0.014	-0.011
	(0.003)***	(0.003)***	(0.003)***
ln(distance to extension service)	0.004	0.006	0.004
	(0.002)	(0.002)***	(0.002)*
Constant	0.117	0.807	0.280
	(0.035)***	(0.034)***	(0.032)***
AIC	-3103.1	-3243.5	-3389.1
BIC	-3054.1	-3194.5	-3340.0
ll	1560.6	1630.8	1703.5
N	769	769	769

* p<0.10, ** p<0.05, *** p<0.01

Annex 5: Panel B&C, FE, and RE Models (Cobb Douglas)

Dependent Variable: log(yield)	B&C	FE	RE
INEFFICIENCY EQUATION:			
Dummy: Land tenure (rent=1)	-0.009	-0.004	-0.008
	(0.007)	(0.007)	(0.007)
ln(age of household head)	0.026	0.008	0.011
	(0.009)***	(0.008)	(0.009)
ln(education of household head)	-0.001	0.000	-0.001
	(0.001)	(0.001)	(0.001)
Dummy: off-farm income=1	0.002	0.005	0.012
	(0.005)	(0.005)	(0.006)**
ln(distance to fertilizer seller)	0.000	-0.003	-0.001
	(0.002)	(0.002)	(0.002)
Gender of household head	0.023	0.015	0.020
	(0.007)***	(0.007)**	(0.007)***
ln(cropped land area)	-0.011	-0.022	-0.014
	(0.003)***	(0.003)***	(0.003)***
ln(distance to extension service)	0.004	0.006	0.006
	(0.002)	(0.002)**	(0.002)**
Constant	0.117	0.830	0.350
	(0.035)***	(0.033)***	(0.036)***
AIC	-3103.1	-3320.2	-3054.6
BIC	-3054.1	-3271.2	-3005.6
ll	1560.6	1669.1	1536.3
N	769	769	769

* p<0.10, ** p<0.05, *** p<0.01