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# The Shifting Effect of One Acre Fund on Agricultural Production Possibility Frontier: An Econometrics Analysis of Treatment Effect Estimation of Maize Yield in Busia County, Kenya

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**Abstract**

Maize is a staple food and its adequacy is a measure of food security in Busia County and across Kenya. Despite myriad efforts to increase its yield, the national level has remained low at 1.6 tons/ha relative to world average of 5.5 tons/ha and Busia County experiences much lower yield of 1.2 tons/ha. This low yield in the county coupled by high population growth rate arising from a fertility rate of 6 percent in the county when national level is 4.6 percent and a large population of women within productive age puts the county's food security at stake. In attempts to support maize farming, One Acre Fund, a non-governmental organization has intervened through provision of farm inputs such as fertilizer and seeds as well as extension services among others. Thus this study sought to investigate the effect of interventions by One Acre Fund on maize yield in Busia County in Kenya. The study used primary data collected from a sample of 264 maize farmers' family heads using questionnaires. The county was first stratified into seven constituent sub-counties out of which two sub-counties, Nambale and Teso North were randomly selected. The study sample was then drawn randomly from these two sub-counties. Robust regression result showed that improved inputs (using certified seeds and organic fertilizers as proxies) and organic manure had the effect of increasing maize yield. Propensity score matching estimation results using three matching algorithms interchangeably which are: nearest neighbor, kernel matching and radius matching with a radius of 0.01 indicated that One Acre Fund farmers managed to achieve significantly higher yields than similar non-members. The study recommends expansion of One Acre Fund membership and increased use of organic and inorganic fertilizer.

**Keywords:** Maize yield, One Acre Fund, Busia County, Propensity Score Matching, Average Treatment Effect on the Treated, improved inputs

## 1. Introduction

Maize is believed to have been in Kenya by 1880s but its transition to a major crop in the country occurred during the World War 1, a period within which diseases struck out millet (the then stable food in Kenya) resulting to millet seeds being eaten instead of being planted (Smale, De Groote & Owuor, 2006). Maize has since then become a key crop to Kenya's economy and beyond especially in Sub-Saharan Africa (SSA) and other developing nations. In Kenya, it is a staple food for about 96 per cent of Kenyans with one of the world's largest per capita consumption that has over time averaged around 125kg (Byerlee & Eicher, 1997; Gilbert et al., 1994; Kirimi et al., 2011). Other than being used as a staple food, it is also used as fodder, industrial raw materials for products like cooking oil, breakfast cereals and exported for bio-fuel production among other uses. It is apparently obvious at least among economists that achieving high economic growth is one of the key macroeconomic goals of all economies. More so, all economies that have ever experienced rapid and sustained economic growth have done so by first curbing food insecurity menace (Juma, 2011). Availability and sufficiency of corn in Kenya is an indicator of food security (Schroeder et al., 2013; Republic of Kenya, 2013). More so, "ugali", a product of maize flour is heavily consumed by Kenyan natives from western part the country.

Enticed by the aforementioned rationale of maize, there have been multidimensional efforts from governmental and non-governmental organizations to scale up the yield of the crop. Among the non-government organizations (NGOs) that have in recent times been greatly involved in supporting farmers especially in the Western part of the country is One Acre Fund (OAF). Thus, this paper sought to estimate the effect of OAF on maize yield in Western region of the country and specifically Busia County. To ensure that we remain within the confines of our intention, and already having introduced the paper, the reminder of it is organized as follows: we proceed by first making attempts to paint the global picture of some facts about the state of hunger and maize yield. We then switch our gears to shade some light on national maize yield variability in Kenya for the period 1975-2012. We motivate our study further by narrowing our discussion onto the comparison in maize yield among the four counties that form the former western province of Kenya where the authors first present the general picture of the entire province before isolating specific details per county. Here we base our argument on the data we compiled across all the districts that were in existence before introduction of counties and aggregated figures of districts which were merged into respective counties. Our discussion then wades into the linkage between our study area (Busia County) and the intervening organization (OAF). The paper then turns its focus to the methodology before presenting the findings. We then end our paper by making brief concluding remarks.

**1.1. Some Stylized Facts about Global Maize Yield and Hunger Prevalence**

Food and Agriculture Organization of the United Nations (FAO), International Fund for Agricultural Development (IFAD) and World Food Program (WFP) (2015) reported that the world's population had ballooned by 1.9 billion in 2015 from early 1990s, a period within which those hungry globally reduced by 216 million (21.4 percent) to 795 million, 780 million of whom resided in the developing regions. This statistics also captures a fall in those undernourished from 18.6 percent in 1990-92 to 10.9 percent in 2014-2016. As such by 2015, 72 developing countries had achieved the 2015 Millennium Development Goal 1(MDG1) of halving the proportion of those in hunger. This reflected a fall in undernourishment level by 167 million in a span of ten years. Hunger prevalence had reduced rapidly in Central, Eastern and South Eastern Asia and in Latin America. North Africa had less than 5 percent of hungry people. Southern Asia tops the list of hunger prevalence with 281 million people undernourished. In SSA, about one in every four people (23.2percent) is in hunger (FAO et al., 2015). According to FAO et al. (2015) and Fischer, Byerlee and Edmeades (2014), this hunger prevalence is majorly attributed to the large potential yield gap in wheat, maize and rice production across the globe but majorly in SSA. FAO et al. (2015) associates this yield gap with failure to adopt optimal input usage and inadequacy in embracing most productive technologies.

Sub-Saharan Africa has a rapid population growth which consumes maize heavily. In the contrary, this region has most of its nations experiencing maize yield below the world's average of 5.5ton/ha and much below the 10 ton/ha for the leading producer, United States (US). This is due to low adoption of improved inputs and lowly mechanized agriculture in SSA (USDA, 2015; 2016). Maize yield is noted to vary considerably across and within continents and even among regions of a country.

**1.2. Trends in Maize Yield and Hunger Variability in Kenya, 1975-2012**

Kenya has an approximate area of 580, 367 km2, of which 567, 137 km2 is Land surface and the rest occupied by inland water bodies. Arid and semi-arid land (ASAL) accounts for 80 percent of the land mass with only 20 percent being arable out of which 12 percent is classed as high potential (adequate rain) and 8 percent as medium potential. Arable land supports about 80 percent of the entire population with nearly 80 percent of the work force being either in agriculture or food processing. Averagely, 3 million families are smallholder farmers accounting for 75 percent of total corn production (Ojwang, Agatsiva, & Situma, 2010; African Agricultural Tecthnology Foundation (AATF) & Kenya Agricultural Research Institute (KARI), 2010; Kirimi et al., 2011). Maize crop takes 56 percent of Kenya's cultivatable land with 98 percent of the small scale farmers planting it (Jayne, Myers & Nyoro, 2008).

In the introductory remarks, it was pointed out that the availability and sufficient of maize is an indicator of food security in Kenya. Despite of this, the country has over years failed to be self-sufficient in corn production and thus remaining a net importer of the crop with the import rising gradually from 2.71 million 90kg bags in 2008 to 3.3million bags in 2012, a period within which the export of corn dropped from 0.21 million bags in 2008 to 0.02 million bags in 2012 (Republic of Kenya, 2013). This importation can also be associated with the fact that corn is the most purchased food item by all households in Kenya. The country's poorest farming households are also net food purchasers with food expenditure taking greatest shares of their budgets. The ultra-poor spend 65-80 percent of their total expenditure on food (Ahmed et al., 2007; FAO, 2015). Averagely about 57 percent of Kenyans are poor with majority depending on rain fed agriculture (Ojwang' et al., 2010).

Despite numerous interventions like provision of subsidized fertilizer, better maize prices, improved seeds as well as input support through National Accelerated Agricultural Inputs Access Program (NAAIAP) to boost agriculture (Republic of Kenya, 2012; 2013), food shortage catastrophe is rampant within the country as shown in Appendix I. The situation may worsen given the rapidly expanding population yet the average yield of corn is too low at 1.6 tons/ha nationally (Republic of Kenya, 2012; 2013), relative to the world's average of 5.5ton/ha (United States Department of Agriculture (USDA), 2015; 2016). Low yield is attributed to harsh climate shown in Appendix I, low rates of improved inputs usage due to financial constraints, poor infrastructure among others (Onono, Wawire & Ombuki, 2013). Kenya has continued to be a hunger victim with at least 10 million of its residence being food insecure and nutritionally poor out of which 2-4 million are in need of emergency food at a particular time (County Government of Busia, 2013). Other than agricultural prosperity and food security in the country being curtailed by resource constraints like inputs quality and availability which many interested parties have strived to address, natural calamities have aggravated the menace. Thus Kenya has experienced a volatile trend in maize production and yield as shown in Figure 1.

 

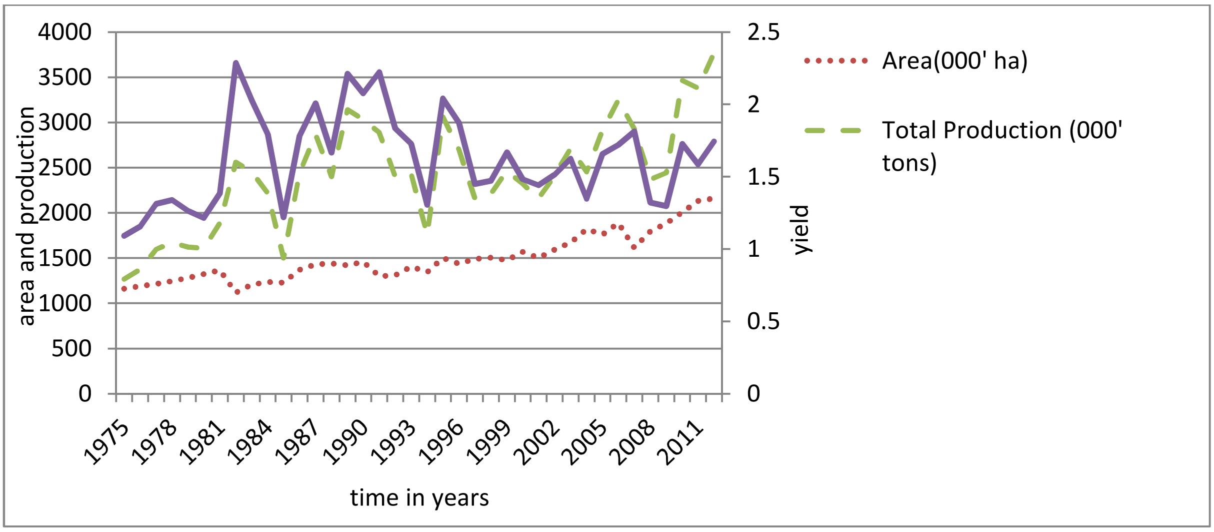


Figure 1. Maize Production in Tons, Acreage and Yield in Kenya 1975-2012
Source: Author's computation and compilation from Kenya agricultural sector compendium (KASDC) 2010 and Economic Review of Agriculture various years.

From Figure 1, it is evidenced that Kenya experiences a volatile pattern in its maize production. Regardless of other factors like increased access to inputs through programs such as NAAIAP, subsidized fertilizer among others being in play that resulted to increase in yield and output between 2011 and 2012, the maize trend is largely attributed to climatic patterns. Harsh weather conditions have been largely to blame for poor maize output since Kenya's agriculture is majorly rainfed. The troughs in production and yield for 1984, 1994-1995 as in Figure 1 can be associated with droughts while El Nino floods explain the trough of 1997-1999. These catastrophic episodes coincide and/or may account for four major food crises in Kenya from 1990: in January 1997, the government of Kenya declared a state of national disaster when severe droughts threatened the livelihood of around 2 million Kenyans. Later in December 2000, 4 million of Kenya's population was in need of food aid after the country was hit by its worst drought in 37 years. Another food crisis stormed in 2004 that resulted from failure of long rains (March-June) and 2.3 million Kenyans needed food assistance. In December 2005 President Kibaki declared another national food catastrophe in regard to famine that struck 2.5 million people in Northern Kenya (Kandji, 2006; Huho & Kosonei, 2014). Other than climatic hindrances, Onono et al. (2013) among others point out high input cost as deterrent against maize productivity.

### 1.3. Maize Yield Comparison among Counties of Former Western Province of Kenya

Western province constitutes four counties; Bungoma, Busia, Kakamega and Vihiga. All the four counties cultivate maize which is milled into flour for making '*ugali*' a staple food for most residents in the region. Maize trend in western province of Kenya has experienced similar volatile trend as the nationwide trend. Such a trend is displayed in Figure 2.

The trend shown in Figure 2 is majorly associated with the unfavorable climatic extremes depicted in Appendix I. Nevertheless other factors are also responsible. For example an upward trend witnessed from 2009 all through to 2011 was due to increased use of fertilizer and farmers shifting from tobacco to maize farming (Republic of Kenya, 2012) while a slight fall in maize production between 2011 and 2012 was due to opening up of new sugar factory in Matete which reduced area under maize (Republic of Kenya, 2013).

The study's main county of interest, Busia County is situated between latitude 0º and 0º 45 North and longitude 34º 25 with an approximate area of 1,830km2 ($1686km^2$ land and $144km^2$ water mass) (Republic of Kenya, 2015). It borders three counties; Bungoma to the North, Kakamega to the East and Siaya to the South. The county has an undulating altitude rising from about 1130M above sea level at the shores of Lake Victoria to a maximum of about 1,500M in the Samia and North Teso Hills. Sandy-loam soil covers a large portion of the county although the Northern and Central parts are covered by dark clay soils. It receives annual rainfall between 760mm and 2000mm, 50 percent of which falls during long seasons with peak between March and late May while short rains accounting for 25 percent occur between August and October. December to February experiences dry spell with scattered rains. The annual maximum temperatures range between $26^0c$ and $30^0c$ with minimum ranging between $14^0c$ and $22^0c$. These conditions make most of the county's regions suitable for varieties of agricultural activities such as growing of maize, cassava, cotton, sugarcane etc (County Government of Busia, 2013; 2014a).

 

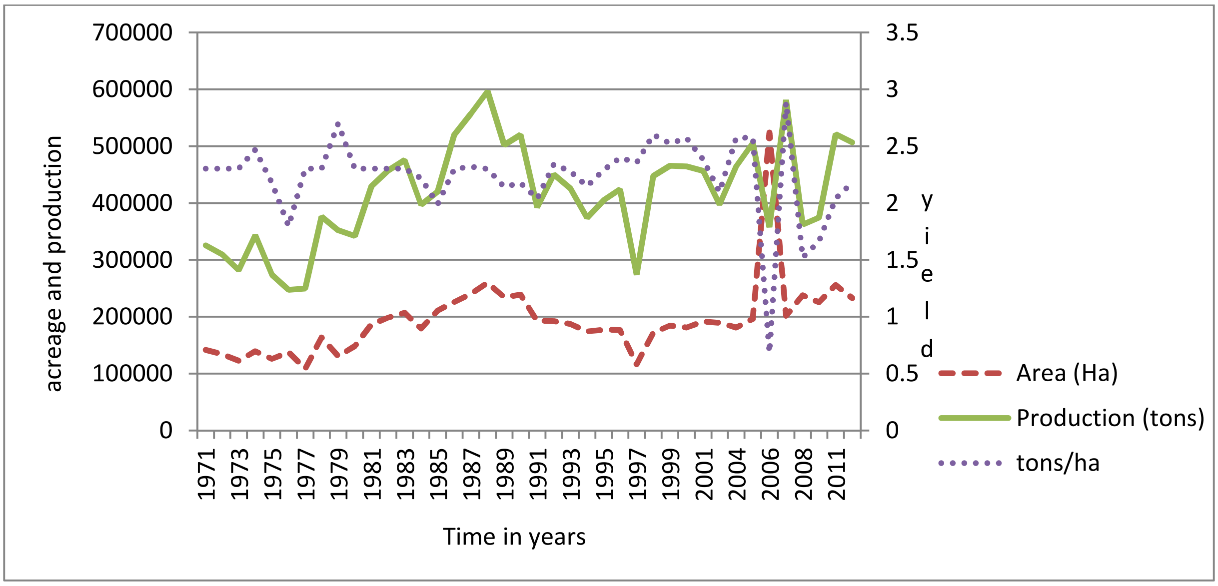


Figure 2. Trends of Maize Yield and Production in Western Province of Kenya
Source: Author's computation and compilation from Kenya agricultural sector compendium (KASDC) 2010 and Economic Review of Agriculture various year

The national population census of 2009 placed the county population at 743,946 in 2009 and was projected to be around 953,337 in 2017. The county has a fertility rate of 6 percent which is above the national average of 4.6percent (County Government of Busia, 2013). This quickly escalating population exposes the County to further population related crisis like poverty and hunger when already 64.2 percent of its population is in poverty and 34 percent of its children below 5years are undernourished while the average national levels of poverty and undernourishment are estimated at 45.7 percent and 30 percent respectively. Out of the total population in Busia County, only 9.1 percent reside in the urban areas with the rest being in the rural. Proportion of the Labor force engaged in family farms is estimated at 71 percent while the remaining 29 percent participate in other activities like fishing, trading and employed in formal and informal sectors. Given that arable land is not big enough to support majority of labor force, it implies that most of them are not gainfully employed and increased unemployment is a challenge too. Generally land ownership is on small scale with each holding on average 2.34 Ha, with minimum of 0.4 Ha and maximum of 6 Ha (County Government of Busia, 2013).

Due to the similarities in myriad agricultural aspects among the four counties, the yield is inclined to assume the same trend with minimal disparities. However, Busia County has experienced relatively lower yield for many periods (though marginally), a good example is from 1993-2006 and 2011-2012 as depicted in Figure 3.

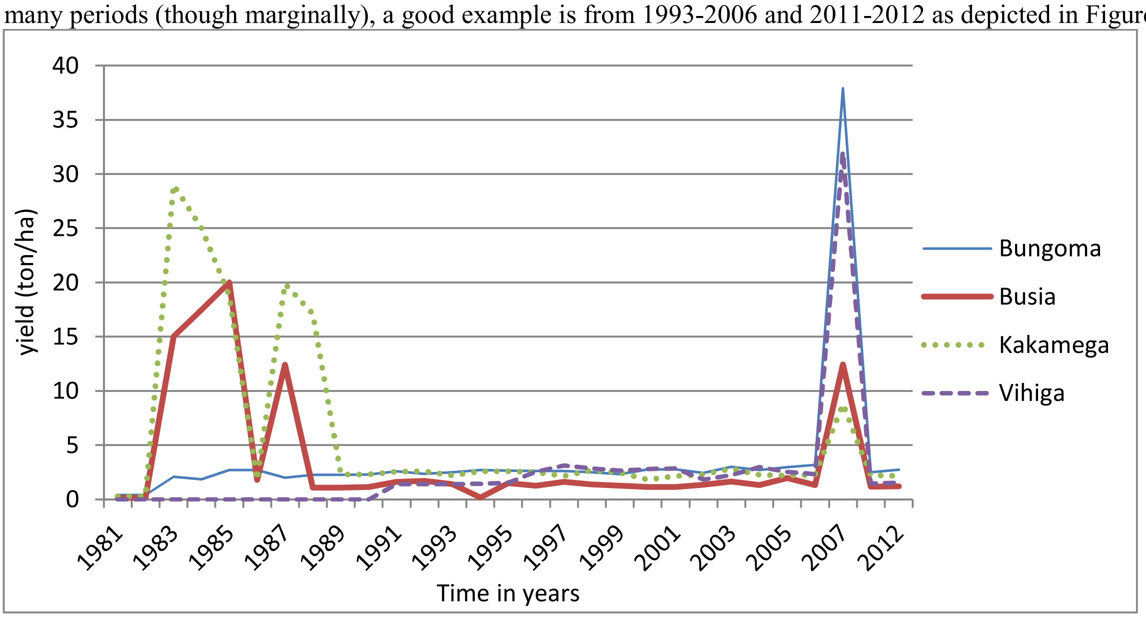


Figure 3. Trends in Maize Yield for Counties in Western Province of Kenya
Source: Author's compilation from Kenya Agricultural Sector Data Compendium (KASDC) 2010 and Economic Review of Agriculture various years

As Figure 3 shows, the low maize yield in Busia County can perhaps be explained by relatively poor soils; many areas of the County especially in Teso North and Teso North Sub-counties are characterized by sandy soil which does not favor maize production and dark clay soils in the Central and Northern parts are relatively less suitable for maize farming compared to fertile soils of sister counties. In the contrary this sandy soil favors cassava production making the county a leading producer of cassava in Western region (former western province) (Republic of Kenya, 2012). In addition the county has had the least adoption of better farming techniques like fertilizer use (Ali-Olubandwa, Odero-Wanga, Kathuri, & Shivoga, 2010). The general variability in the yield for the four counties can be associated (though not wholly) to the destructive climatic variations depicted in Appendix I.

### 1.4. Contextualizing One Acre Fund in Busia County

One Acre Fund is a Non-Governmental Organization (NGO) founded by Andrew Youn and launched in 2006 in Kenya and was headquartered in Bungoma, Kenya before later been shifting the headquarter to Kakamega, Kenya. Its main objective is to help smallholder farmers attain self-food sufficient and fight poverty. It does so by; creating producer groups through conversion of women self-groups into producer groups; providing quality farm inputs namely: seeds and fertilizer among others needed by farmers; giving extension services and training to farmers through OAF field staffs and sourcing better markets for farmers. However, its package is a loan where it takes a portion of the output in repayment of the services it offers (OAF, 2014). In addition, it is broadening its scope to provide input/drought and funeral insurance, cash loans, drying and storage bags, energy loans (solar lamps and improved jikos) among others. Clients were earlier restricted to land size between 0.4 and 1.5 acres (OAF, 2015) but currently permitted to a maximum of 2 acres. OAF has also partnered with respective governments in areas it operates where the partnership includes: input (fertilizer and seeds) distribution, improve extension and training and market stimulation partnership aimed at fostering farmers understanding of input market and supply chain (OAF, 2014). Since its conception in Kenya OAF has extended to Tanzania, Rwanda, Burundi (OAF 2013a; 2014) and is carrying out pilot program in Uganda and Malawi (OAF, 2014).

According to Nyoro (2002), agricultural productivity is affected by seed quality, fertilizer, credit and financial services, land preparation cost, price stability, technological development and extension services. The county government in collaboration with other partners like United States Agency for International Development (USAID), Program for Agriculture and Livelihoods in Western Communities (PALWECO) have tirelessly strived to support agriculture through measures like input provision, acquiring machines for mechanized agriculture, promotion of poultry, dairy and fish farming. PALWECO which is one of the organization with enormous coverage of all sub counties of the entire Busia County had its inception in 2010 and implemented in 2012. This organization receives its funding from joint effort of the governments of Kenya and that of Finland with the prime objective of poverty reduction and improving livelihoods and standards of living of the people of Busia. The primary beneficiaries of PALWECO (estimated at 480,000 in 2012) are poor families. The activities of PALWECO are skewed towards agricultural and livestock support, water and rural infrastructure namely market places and roads (PALWECO, 2012). It is thus apparent that OAF operates besides other organizations in the region.

Despite several interventions, Busia County Government admits that challenges of monitoring, evaluation system and inadequate infrastructure in addition to high farm input cost, adverse marketing infrastructure, deteriorating soil fertility, poor linkage between farmers and research and extension services and climatic dynamics still persist (County Government of Busia, 2014b; 2015). It is the belief of the authors that OAF is well placed to address most of these challenges especially through its close conduct with farmers via its widespread field staffs. In its own view, OAF argues that it has made great milestone in shaping the lives of its clients and achieving its goals. Statistics show that the OAF is self-sustainable, its clients have recommendable returns on investment (ROI) exceeding non-members by far and the number of farm families supported is rising rapidly (OAF, 2013a; 2014). One Acre Fund and entire agricultural community believe that being mindful of environmental impacts and mitigation of climatic change risk via sustainable intensification can see acreage yield of food in rural Kenya matching that of the United States (US) (OAF, 2013b).

## 2. Literature Review

For decades now, most if not all empirical evidence has unanimously assented to the view that improved inputs and other modern farming practices have the potential of bridging the yield gap. These previous works have explicitly demonstrated that policies which ease access to such inputs by farmers is a step in the right path of shifting the agricultural production possibility frontier outwards.

De Groote et al. (2005) relied on nationwide unpublished data for 1992 and 2002 from a survey conducted by International Maize and Wheat Improvement Centre to examine how use of improved inputs including fertilizer among other variables affect maize yield in Kenya. Variables of interest were personal characteristics of farmers and those of their farms, their usage of improved inputs (seeds and fertilizer) and their access to credit and extension services among other agricultural services. Logistic regression results showed that fertilizer use relates positively and significantly with extension services but this relationship is negative for the case of cattle ownership and farm size. On the other hand, Ordinary Least Square (OLS) results revealed that high fertilizer usage led to high yields. Nevertheless, the results were mixed for improved seeds; in some regions it was positive and negative in others; implying that seed variety is soil-type sensitive. Expansion of extension services and development and use of area-specific seeds was recommended to increase yield.

In the inquiry into the merits of using improved inputs on maize productivity in Uganda, Okoboi (2010) interrogated the 2005/2006 Uganda Nationwide data collected at household and community level by Uganda Bureau of Statistics (UBoS) and obtained from Uganda National Household Survey (UNHS). A total of 1888 farms were considered and both yield and gross profit functions modeled as stochastic frontier functions were estimated using the Maximum likelihood Estimation (MLE) technique. The study findings revealed that although the use of improved inputs such as seeds and fertilizer boosted yields significantly, marginal cost of such inputs was much higher relative to the additional revenue derived from the increased output arising from the use of these improved inputs. In addition, farmers who used improved but home-saved seeds without fertilizer registered lower yields but rather higher gross profits. Even though econometric results revealed inverse relationship between land size and yield, extension services were noted to significantly boost yield.

Ali-Olubandwa et al. (2010) carried out a study aimed at establishing how adoption of improved maize production practices relates to maize yield among smallholder farmers in Western province of Kenya during an agricultural reform era. Four districts of Lugari, Bungoma, Busia and Mt Elgon were selected purposively and a sample of 200 smallholder farmers drawn from these districts using systematic sampling criteria. Data was obtained with the help of open and closed ended questionnaires. Descriptive, correlation, multiple and stepwise linear regression analysis established that maize yield responds positively and significantly to adoption of improved inputs. Lugari district portrayed the highest yield probably because; most farmers had attained secondary education and above, had adopted the technology as a package and not partially and most farmers relied purely on farming for a living.

Kipng'eno (2012) investigated how the NAAIAP influences maize production among farmers in Nyamarambe Division in Kisii County of Kenya. The researcher examined the extent to which farmers' group training affects maize production, how farm follow up visits, access to free agricultural inputs and holding of farmer field days shapes maize production. Questionnaires were administered to a sample of 120 beneficiaries of NAAIAP selected randomly. The responses were subjected to descriptive analysis. Results indicated that maize production is positively influenced by access to free inputs, farm field days, group training and farm follow up visits.

Schroeder et al. (2013) explored the reasons behind low rates of adoption of hybrid maize varieties among smallholder farmers in marginalized areas of Kenya. Data collected from 200 households in the Kilifi and Kwale Districts of the former Coast Province of Kenya was subjected to logistic regression to analyze explanatory variables that affect adoption of improved maize varieties. The regression output revealed that contact and proximity to extension center, listening to agricultural radio programs, credit availability and participation of farmers in training positively and significantly favored adoption of improved maize varieties. However, insignificant effect was noted in household size and literacy level. Adoption of the improved inputs was also recommended for it was argued to increase yield.

Onono et al. (2013) investigated how maize production in Kenya responds to both price and non-price incentives using 1972-2008 published secondary data obtained from various sources. The least square regression results revealed positive response of maize output to own price, agricultural development expenditure, sale of maize to marketing board, inflation, per capita growth in Gross Domestic Product (GDP), liberalization, favorable weather, governance reform of 2003-2008 and the access to cheap fertilizer. However, negative response was noted on the failed coup *d'état* attempt of 1982. Elasticity estimates revealed elastic response of maize to inflation and real per capita GDP but inelastic to the rest of the variables. Inelastic response to fertilizer price was argued to be due to low uptake of fertilizer while from output price is due to lagged effect. They recommended that both price and non-price factors be addressed to catalyze maize production.

Mucheru-Muna et al. (2014) investigated how the application of organic and inorganic fertilizer enhanced maize productivity and profitability among small scale farmers in Central Kenya. With the help of analysis of variance (ANOVA) approach, the results showed that those farmers who used organic manure and inorganic fertilizer improved their yields much more than those who used either organic or inorganic separately. However, those who applied organic manure alone had better yields and returns than those that relied purely on chemical fertilizer; indicating superiority of organic manure over chemical one. Results also showed serious cases of soil degradation among users of chemical fertilizers, thus endorsing use of manure if soil management and conservation is of interest.

Ogada and Nyangena (2014) used improved maize varieties and inorganic fertilizers as proxies of advanced technology to examine how such inputs affect maize yield in Kenya. The study relied on Kenya's panel data for

2004 and 2007 adapted from Tegemeo Institute pertaining 1342 agricultural households. The data was nationwide excluding Nairobi and North Eastern province where farming is hardly done. Propensity score matching (PSM) and Difference-in-differences (DID) results showed that embracing improved technologies increases yield. Moreover it was noted that adopters of a complete package namely; planting fertilizer, improved maize varieties and top dressing fertilizer outdo their partial-adopter counterparts who also get more yields than total non-adopters. They inferred that package adoption is highly effective among medium yielding groups but any form of adoption may not be appealing to high yielding groups for they are already at the upper brink of productivity. On the other extreme, low yielding groups can use partial adoption just as an interim and start point move but not as a sustained approach.

Adebayo and Olagunju (2015) sought to establish the extent to which the use of innovation in agriculture impacts on the productivity outcomes and improved livelihoods among smallholder farmers in Rural Nigeria. They relied on Primary data obtained with the aid of structured questionnaires backed by personal interview collected from a sample of 360 households (120 yam farmers, 120 maize farmers and 360 cassava farmers) selected using multistage sampling technique among residents of entire Oyo state in South West region of Nigeria. The study relied on PSM model and first differencing. The findings indicated that agricultural research interventions driven by agricultural innovation significantly impacted on both rural incomes and outputs and still have the potential of doing so. The study recommended for intensified capacity building of the local extension agents and heightened budgetary allocation so as to enhance agriculture research program that will spur improved productivity and better livelihoods.

## 3 Methodology

### 3.1. Study Area, Target Population, Sampling Technique and Data Type

The study targeted maize farmers (both OAF members and non-members) in Busia County during March – August 2016 maize farming season. Based on the Busia County profile of 2016, the county was estimated to have a total 98,099 farm families. The distribution of farm families among the constituent sub-counties of Busia County is: 13,826, 15,705, 20,000, 12,750, 8,700, 5,985 and 21,133 in Matayos, Nambale, Butula, Samia, Bunyala, Teso North and Teso South sub-counties respectively. Among these about 97 percent (95,156) farm families carry out maize farming. Cross-sectional data was collected from 264 respondents using simple random sampling from two of the sub-counties, Nambale (174) and Teso North (90).

### 3.2 Estimation Procedure

To achieve the study objective, the authors conducted a two stage estimation procedure. The first step was conducted followed by the second one so as to sufficiently isolate the effect on maize yield caused by OAF participation from that resulting singularly from nature of inputs. In the first stage, we estimated a log-linear Cobb-Douglas production function represented by equation (1) to estimate how various inputs affect maize yield. For interest of brevity modelling process that generated equation (1) is not presented here.

$$logY_i = \psi + \theta_1 S_i + \theta_2 D_i + \theta_3 D_i^2 + \theta_4 C_i + \theta_5 M_i + +\alpha_s logLS_i + \alpha_l logL_i + \mu_i$$
$$i = 1,2 \dots ,264 \qquad (1)$$

Where; $Y$ is the yield, $S$ captures seed type, $LS$ −land size, $D$ – quantity in Kg of fertilizer for planting (all farmers who had used inorganic fertilizer during planting had used diammonium phosphate (DAP)) and $D^2$ is its square, $C$ − quantity in Kg of top dressing fertilizer which was mainly calcium ammonium nitrate (CAN), $M$ – manure, L-labor hours and μ is an error term while the parameters $\theta_1 to\ \theta_5$ were respective coefficients, $\alpha_s$ and $\alpha_l$ measured respective elasticities 264 was the sample size. Equation (1) was estimated using the robust linear regression after the data failed to pass multicollinearity, normality and homoscedasticity tests.

After the estimation of equation (1) the authors conducted a treatment effect estimation using propensity score matching technique so as to establish the average treatment effect on the treated (ATET) of OAF on yield. Prior to ATET estimation, a logistic estimation captured by participation model in equation (2) was conducted with subsidiary outcome being propensity scores which reflected the probability of a farmer joining OAF given observable covariates, after which overlap and balanced assumptions were verified and the results showed that matching procedure had fulfilled these assumptions.

$$\Lambda(x\gamma) = \frac{\exp(\gamma_0 + \gamma_1 x_1 + \cdots + \gamma_7 x_7)}{1 + \exp(\gamma_0 + \gamma_1 x_1 + \cdots + \gamma_7 x_7)}$$

$$where \quad 0 < \Lambda(x\gamma) < 1 \qquad (2)$$

Where $x_1$ to $x_7$ represent maize farmer’s sex, age, age squared, marital status, household size, sub-county of residence and level of education respectively.

Propensity score estimation and thereafter verification of PSM assumptions was proceeded by ATET estimation using three matching algorithms namely nearest neighbor with replacement, kernel method and finally radius matching using a radius of 0.01. The modelling of the equation to estimate ATET is not also presented here but we only give the final equation estimated (equation 3) which can be condensed into equation (4)

$$ATET = \frac{1}{ꞥ-ῆ}\left[\sum_{i=1}^{ꞥ-ῆ}(1-D)Y_O + D\,Y_1\right] - \frac{1}{ῆ}\left[\sum_{i}^{ῆ}(1-D)\,Y_O + DY_1)\right] \quad (3)$$

Where $Y_1$ is maize yield for a farmer who is OAF member and $Y_0$ is respective counterfactual while ATET is the average treatment effect due to OAF. ῆ Represents units (farmers) in control group (OAF non-members) that were successfully matched with $ꞥ - ῆ$ units in treated group (OAF members) and ꞥ is the total number of farmers who were successfully matched. ꞥ is not necessarily equal to the sample size $n = 264$; so that $ꞥ \leq 264$. Note that D=1 for the first right hand term of equation (3) while D=0 for the second term. Thus equation (3) simplifies to;

$$ATET = \frac{1}{ꞥ-ῆ}\left[\sum_{i=1}^{ꞥ-ῆ} Y_1\right] - \frac{1}{ῆ}\left[\sum_{i=1}^{ῆ} Y_O\right] \quad (4)$$

**4. Results and Discussion**

**4.1. Effect of various inputs on maize yield**

To estimate the effect of various inputs on maize yield, equation (1) was estimated by the robust linear regression approach which has the power of circumventing the non-conformity to the classical linear assumptions. The regression results extract are presented in Table 1

Table 1. Effects of various Inputs on Maize Yield

| Dependent variable: log of maize yield in bags per acre | | | |
|---|---|---|---|
| **Exogenous Variables** | **Coefficients** | Robust Standard error | p-value |
| Seed type | 0.1359175 | 0.1168824 | 0.246 |
| Quantity of DAP in planting | 0.0151773 | 0.0055368 | 0.007*** |
| DAP squared | -0.000178 | 0.0000534 | 0.001*** |
| Quantity of CAN in top-dress | 0.0025831 | 0.003218 | 0.423 |
| Quantity of Organic fertilizer | 0.0002267 | 0.000048 | 0.000*** |
| Log of land size | -0.7360546 | 0.1262599 | 0.000*** |
| Log of labor hours | 0.499968 | 0.1209383 | 0.000*** |
| Constant | 1.327548 | 0.1800833 | 0.000*** |

**Note: *** represents significant at 1%**

The regression results summarized in Table 1 revealed that farmers who used certified maize seeds recorded an average log of maize yield of 0.1359175 more than those who used uncertified seeds such as from previous seasons' harvests. This effect was however insignificant. The positive relationship between seed type and yield as found out in this study supports the findings of Nyoro (2002) who argued that access to high quality maize seeds is a prerequisite for high productivity. The low yield associated with non-hybrid seed was linked to such seeds being neither certified, cleaned from weeds nor treated and thus suffer from contamination (Nyoro, 2002). In another related study, De Groote et al. (2005) found mixed results; in some regions, the effect of hybrid seed was positive while negative in some, suggesting that seed variety is soil-type sensitive.

The estimated results in Table 1 as evidenced by the coefficient (0.0151773) and p-value (0.007) show that the quantity of DAP fertilizer used at the time of planting has a positive and significant effect on the yield of maize. In particular, increasing the quantity of DAP by 1kg ceteris paribus, increases the log of maize yield in bags by 0.0151773. The effect of using inorganic fertilizer in top-dressing was noted to be positive but insignificant. This finding confirms the work of De Groote et al. (2005), Okoboi (2010), Ogada and Nyangena (2014) and Ali-Olubandwa et al. (2010) who also found positive effect of inorganic fertilizer use on maize yield. It is also worth noting that we included the square values of DAP to capture a quadratic relationship between DAP and yield because highly extreme levels of DAP would be unfavorable for maize farming and thus assuming a linear relationship at all levels of DAP use would be inappropriate.

The results showed further that the use of organic manure had a positive and highly significant effect on the yield of maize as reflected by the coefficient value of 0.0002267 and the corresponding p-value of 0.000. Similar results were found in the study by Mucheru-Muna et al (2014) where the use of organic manure was noted to have a positive influence on maize yield. Moreover, our findings revealed a negative influence of land size on maize yield. In particular, it was estimated that an increase in land under maize by 1% lowers the yield in maize by 0.7360546% ceteris paribus. This finding was in agreement with that of Okoboi (2010) who found a negative effect of land size on yield. Based on our experience and interaction with the respondents, we argue that the negative effect of land size on yield in probably caused by farmers ability to manage the crop all through from land preparation to harvesting. i.e. this ability tends to diminish as the size of land increases. In addition, the findings showed a positive and highly significant effect of labor hours on maize yield.

### 4.2. Effect of One Acre Fund on Maize Yield

To estimate the effect of OAF on maize yield, we started by estimating equation (2) using the treatment effect procedures and the results are shown in Appendix II. In addition to results in Appendix II, the estimation of equation (2) yielded propensity scores as complimentary outputs, though not presented here. We then proceeded to conduct the overlap and balanced assumptions using the visual plots. The results for these two tests are appended as Appendix III and IV respectively. From Appendix III, neither of the two plots shows too much probability mass near zero or one and the two densities estimated show most of their respective masses within regions in which they overlap with each other. This implied non-existence of evidence that the overlap assumption had been violated. This ensured that farmers with the "same" covariates had positive probabilities of either being OAF members or non-members. Appendix IV shows that the covariates pass the balancing test. Ideally the main aim of balancing test was to ensure that OAF membership was independent of farmers' characteristics after conditioning on the observable features as estimated by the propensity scores.

Finally, the authors conducted the ATET estimation based on equation (3) which is a replica of equation (4) and the results using the three matching algorithms summarized in Table 2. The three matching algorithms were used to provide robustness checks and ensure that results do not depend on estimation method.

Table 2. Results for Estimation of ATET of One Acre Fund on Maize Yield

| Dependent Variable: Average Maize Yield | | | | |
|---|---|---|---|---|
| | N | | | |
| Matching Algorithm | **OAF member** | **OAF non-members** | ATET | t-value |
| Nearest neighbor with Replacement | 138 | 71 | 3.385<br>(1.026)<br>[0.892 ] | 3.793 |
| Radius matching with a radius of 0.01 | 133 | 115 | 2.420<br>(0.918 )<br>[1.077 ] | 2.246 |
| Kernel method | 138 | 122 | 3.603<br>[0.735] | 4.901 |

Note: Each row reports estimates using a different matching algorithm; (1) nearest neighbor using one neighbor; (2) radius matching using a radius of 0.01; (3) Kernel matching using normal density function. Respective values for $n$ represent number of farmers in OAF and those not in OAF that were succefully matched. Standard errors in parenthesis and bootstrapped clustered standard errors in lower brackets. T-values are based on bootstrapped method

The estimates for all the three matching approaches show that OAF member farmers experienced significantly higher maize yield compared to their comparably similar non – members. In the treatment effect jargon, the average, ATET due to OAF were 3.385, 2.420 and 3.603 bags per acre using nearest neighbor, radius matching and Kernel matching respectively. In the ordinary terminology, the ATETs presented indicate the yield an average farmer who is an OAF member gets above a similar non-member. In particular, the results using the nearest neighbor method shows that, on average, an OAF maize farmer harvested 3.385 bags of maize per acre than a "similar" OAF non-member maize farmer. Similar intuition can be applied to interpret the results corresponding to radius and kernel matching methods. These finding imply that OAF helps farmers to increase their maize yield.

### Conclusion and policy recommendation

The findings of this study indicated that use of hybrid and inorganic fertilizer for top-dressing were positive but insignificant. The paper however established positive and highly significant effects of inorganic fertilizer used during planting and organic manure on the yield of maize. This implies that Busia County maize farmers have the potential of increasing their yield if they embrace use of these inputs. More so, the ATET results indicated that members under OAF managed to record higher maize yield relative to their non-member counterparts. The implication of this is that OAF was able to shift the production possibility frontier of maize higher.

Based on the study findings, we argue in favor of increased usage of hybrid seeds, organic and inorganic fertilizer which have the tendency of increasing yield. In particular, we highly encourage maize farmers to embrace use of farm manure. More so, farmers through their own efforts as well as by the help of governmental and non-governmental activities/measures should increase adoption of hybrid seeds and chemical fertilizer. In line with the ATET results, the authors advocate for increased enrolment into OAF as the organization has the ability of increasing maize yield.

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**Appendices**

Appendix I: Climatic Hazards and Population Affected in Different Parts of Kenya from 1970-2012

| Year | type of disaster | area of coverage | Impact |
|---|---|---|---|
| 2012 | Floods | Nyanza/Western | 84 people killed, 30,000 displaced About 280,000 people affected countrywide |
| 2012 | Drought | Widespread | 3.75 million people in dire need of food by July 2012 |
| 2011 | Drought | Garissa,Isiolo,Wajir,Mandera Mombasa,Marsabit,Nairobi,Turkana Samburuand Turkana Counties | 4.3 million people were in dire need of food |
| 2010 | Floods | Budalangi, Tana river, Turkana | 73 killed, 14,585 people affected |
| 2009 | Droughts | Widespread | 70-90% loss of livestock by Maasai pastoralists |
| 2007/2008 | Drought | Widespread | 4.4 million people affected, 2.6 million people at risk of starvation, up to 70% loss of livestock in some pastoralcommunities |
| 2006 | Drought | widespread | 3.5 million in need food by September. 40 human lives lost and about 40% cattle, 27% sheep and 17% goats lost |
| 2006 | Floods | Widespread | 7 deaths, 3,500 people displaced |
| 2005 | Drought | Widespread | 2.5 million People close to starvation. Declared a national disaster |
| 2004/2005 | Floods | Budalangi, Nyando | 34000 people affected |
| 2004 | Drought | Widespread | About 3 million people in need of relief aid for 8 months to March 2005 |
| 2003 | Floods | Nyanza/Westen, Tana River Basin | 60,000 people affected by severe floods (28000 in Budalang'i) |
| 2002 | Floods | Nyanza, Busia, Tana River Basin | 150,000 people affected |
| 1999/2001 | Drought | Widespread | 4.4 million people affected |
| 1997/1998 | El nino floods | Widespread | 1.5 million people affected |
| 1995/1996 | Drought | Widespread | 2 million people affected (1.41 million in ASAL). Declared a national disaster |
| 1991/1992 | Drought | ASAL zone | 1.5 million affected |
| 1985 | Floods | Nyanza/Western | 10000 people affected |
| 1983/84 | Drought | Widespread | 200000 people affected |
| 1982 | Floods | Nyanza | 4000 people affected |
| 1980 | Drought | Widespread | 40000 people affected |
| 1977 | Drought | Widespread | 20000 people affected |
| 1975 | Drought | Widespread | 16000 people affected |
| 1971 | Drought | Widespread | 150000 people affected |

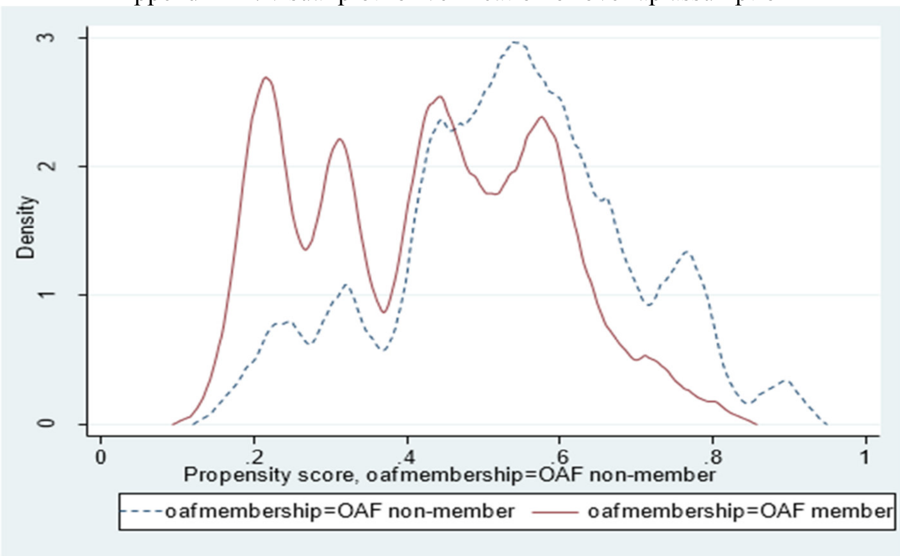
Source: Author's compilation from ojwang' et al (2010) and Huho& Kosonei(2014)
Source: Author's compilation from ojwang' et al (2010) and Huho& Kosonei(2014)

Appendix II: logit estimation of participation into One Acre Fund

```
Logistic regression                             Number of obs   =        264
                                                LR chi2(7)      =      30.69
                                                Prob > chi2     =     0.0001
Log likelihood = -167.37199                     Pseudo R2       =     0.0840
```

| oafmembers~p | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| sex | -.4217932 | .2655567 | -1.59 | 0.112 | -.9422747 | .0986883 |
| age | .2035283 | .08064 | 2.52 | 0.012 | .0454768 | .3615798 |
| agesq | -.0020861 | .0008707 | -2.40 | 0.017 | -.0037927 | -.0003795 |
| Mariage | -.3134709 | .1622905 | -1.93 | 0.053 | -.6315545 | .0046127 |
| hhsize | -.0963832 | .0508752 | -1.89 | 0.058 | -.1960968 | .0033303 |
| residenc | -1.081131 | .2863971 | -3.77 | 0.000 | -1.642459 | -.5198026 |
| educ | .0807962 | .1631552 | 0.50 | 0.620 | -.238982 | .4005744 |
| _cons | -2.749674 | 1.797452 | -1.53 | 0.126 | -6.272616 | .7732677 |

Appendix III: visual plot for verification of overlap assumption




Appendix IV: verification of the balancing test