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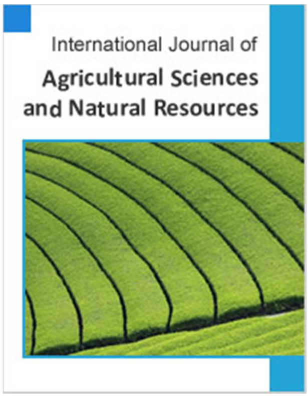

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Adoption of Improved Varieties and Input Elasticities Among Smallholder Maize Farmers in Kabarole District-Western Uganda

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Abstract
The study examined adoption of improved maize varieties and output response to inputs among smallholder farmers in Kabarole District Western Uganda. The specific objectives of the study were: to estimate and compare input elasticities of nitrogenous fertilizer, seeds, labour, plot size and herbicides for improved and local maize and to determine multi-factor productivity for improved and local maize. The study used cross-sectional design and primary data were collected using a questionnaire from four sub-counties of Rwimi, Kibiito, Rutete and Kasenda. Input elasticities of labour, nitrogen fertilizer, maize plot, seeds and herbicides were obtained by estimating the Cobb-Douglas production function model. Output response to all inputs studied was more elastic for adopters, whereby any percentage increase in input use resulted into a more than one percent increase in yield. Multi-factor productivity calculated (7.14) indicates the potential to increase maize productivity by combining all inputs studied, thus suggesting the need for small holder maize farmers to adopt all inputs as a package if they are to obtain potential output. In terms of policy, the study recommends that the government should subsidize all improved inputs for all farmers to be able to afford them and apply them together.

1. Introduction

About 86 percent of Uganda's rural population grows maize (*Zea mays* L.) [1]. The crop is among the five priority crops (including banana, rice, cassava and millet) targeted countrywide under the Development Strategy Investment Plan (DSIP) of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) [2]. The crop is a major staple for most urban poor and institutions, mainly schools, hospitals and military institutions [3]. Despite the importance, maize productivity is low and production is mainly at subsistence level, characterized by low adoption of improved technologies, heavy reliance on natural soil fertility, local seed and family labour. A couple of such factors are responsible for low maize yield estimated at 1.94 tons per hectare (t/ha) compared to global productivity of 4.7t/ha per season [4] and the Uganda's and global potential yield of 7.5 t/ha and 8.0t/ha respectively [1, 4].

With adoption of improved maize varieties, input elasticities of fertilizers, herbicides, labour, plot size and seed are expected to improve. Thus, food productivity will be enhanced to overcome food insecurity problem, which according to [5], is among the world's top ten risks posing more threat than AIDS, Tuberculosis and Malaria combined. However, [6], indicated low use of purchased inputs mainly agro-chemicals and improved seed in the Sub Saharan Africa (SSA). The study by [7] posted lack of means to purchase improved technologies as the major barrier faced by many smallholder farmers in the region. Low adoption scenario negatively affects the potential of most countries to achieve the green revolution.

Improved maize varieties grown are categorized under Open Pollinated Varieties (OPV) or longe series and *Hybrid* varieties [8, 9]. According to [10], an improved variety differs from the local seed in terms of yield potential, maturity period and adaptation to drought, pests and diseases. Compared to improved varieties, [7] and [10] noted that local maize can be saved from one generation to the other, but is vulnerable to water stress. Within improved varieties, OPVs/ *longe* series can also be recycled up to three years but *Hybrid* varieties give comparatively higher yields. Farmers have to be advised on the best improved variety to plant depending on the soil and environmental conditions. However, both (improved varieties) give higher yields than *Local* maize [11].

Improved maize is superior to local maize perhaps due to higher response to other inputs such as fertilizers and herbicides. Improved maize is more resistant to weeds, pests and disease. Nutritionally, improved maize contains a higher proportion of protein and calories compared to local maize [10]. This is a much desired remedy to malnutrition which has hit many income-constrained families in the SSA.

According to [12], an improved variety must be bred to conform to the International Union for the Protection of New Plant Varieties (IUPV) criteria. The population resulting from the breeding should be distinct, uniform and stable. However, an improved maize variety, as used in this study, refers to *Longe* series or *Hybrid* maize obtained from a certified seed dealer and planted by farmers for the first time. *Local* maize on the other is the one selected from previously grown irrespective of whether it was previously OPVs or *Hybrid*. Adopters, in this study, refer to farmers that planted an improved maize variety and non-adopters are those that planted local/recycled maize.

From the discussion above, planting improved varieties (*Longe* series and *Hybrid)* is more advantageous than local maize. However, in spite of these advantages, it is largely unknown, whether there are differences in input elasticities between improved and local maize among smallholder farmers in Kabarole District.

If there are differences in input response to improved and local maize, it therefore means that input constraints will hinder an improved variety from achieving its productivity potential hence affecting its sustainability (adaptation) [13]. Not only availability of an input matters but also agronomic-related issues such as time, method and quantity used. For example, the type, time and method of application of a fertilizer determine the output obtained from a given crop like maize. Relatedly, a study by [14] noted a negative relationship between use of agro-chemicals and maize output and suggested incorrect application as the major reason. The input and output prices also determines quantities of input used. For example, [9] observed that the demand for fertilizer and labour had a direct bearing on maize out price. As maize price increased, there was increase in the redistribution of gains accrued to buying fertilizer and paying landless labourers.

Due to complementarities in technologies as discussed above, [10] argue that realizing a high output from improved varieties requires another improved input such as nitrogen fertilizer and agro-chemicals. In line with this, as argued by [15], there was higher productivity of improved seed and fertilizers for maize crop under chemical weed control option than manual weed control. Similarly, [16] observed that planting improved maize seeds without applying fertilizers had slightly lower yield compared to that obtained when fertilizers are applied, but lower profit margin due to the higher marginal cost of fertilizer compared to the marginal revenue obtained because fertilizers are expensive. However, in a separate study by [3], it was emphasized that economic returns that accrue from the use of improved technologies is more critical in promoting their adoption than yield per se.

In Kenya, [17] estimated that a one percent increase in use of inorganic fertilizer would increase maize yield by 17 percent. A lower input elasticity of about 5 percent was later obtained in Ghana by [14] while, [18] obtained only 4 percent fertilizer input elasticity. However, this depends on the fertilizer price and input agronomics such as type of crop and fertilizer, time and method of application. The study by [19] observed that maize output negatively responded to fertilizer prices, whereby a one percent increase in fertilizer price would reduce maize output by 0.4 percent. It was also observed in the study by [17] that maize farmers in Kenya who also grew tea, applied NPK fertilizer meant for tea on maize crop yet it is not right for maize. Thus, farmers realized low output yield response. This study was conducted from Kenya which has socio-economic and agro-ecological conditions different from those of Uganda.

Plot size was also found to be negatively related to maize productivity whereby, an increase in the area under maize by one hectare would reduce maize output by 41 percent [16]. This is possibly because as the acreage increases, farmers' attention and management per unit reduce. It can also be due to imperfect land and labour markets, particularly lack of strict supervision of family labour when producing on large scale and the combination of other inputs such herbicides and fertilizers. The inverse relationship can also be explained by higher land conservation efforts on smaller than larger plots. The results about land input elasticity in Uganda by [16] contradicts those obtained by [15] in Nigeria, [20] in

Ghanaand [9] in Bangladesh, where a positive correlation between plot size and maize output was observed.

Maize yield increases considerably with herbicide treatment due to increase in per ear grain number, seed weight, length and kernel rows [21]. Maize output was also significantly higher on plots that were sprayed with herbicides such as Atrazine and 2, 4-D (Calliherbe and bextra) than those hand-weeded at early stages; possibly because the latter is labour intensive, time consuming, causes chronic pain, spinal deformation and weeds re-appear immediately after it is applied [15]. However, herbicide treatment did not significantly increase the number of cobs per plant since the character is genetically controlled [22].

There are variations in the effect of different types of herbicides on maize yield. Higher grains per cob and therefore higher yields (5.15 t/ha) were recorded on plots treated with Gramaxone (post-emergence) compared to Stomp 330 E (pre-emergence) which had only output of 3.94 t/ha [22]. However, all plots treated with herbicides significantly gave higher maize grain output compared to the control plots [23]. They further observed that output response to herbicide application depended on the amount of herbicide applied. Application of full doze of foramsulfuron + isoxadifen-ethyl (1125 ai/ha) produced 4.46 t/ha. With the reduced doze of the same herbicide, yield significantly reduced by 3 percent. The use of herbicides is a major a remedy to high labour intensities especially in peak cropping times. About 80 percent of the smallholder farmers would increase maize acreage if weeds were not a problem [15]. As opposed to these findings, in the Nigeria's state of Edo, yam farmers who used agro-chemicals had in general, an input elasticity of -0.008 percent, citing over-utilization [18].

As noted by [9], labour is the main variable input of maize production. Labour (normally disaggregated into family, social and hired labour) is required to carry out a number of farm activities such as land preparation, planting, weeding, fertilizer application and harvesting. A study by [24] established a 0.01 unit increase in maize output for every additional man-day. While [25] observed that up to 7 percent increase in maize output could be realized with one man-day increase. However, in both studies, the effect was not significant. In Kenya a higher output response to labour of up to 42.2 percent was reported by [17]. All these studied labour in general. There is need to examine maize output response to different forms of labour namely, family, hired and social labour.

Uganda's estimated labour productivity on maize crop is 5.8 kg/man-day. Eastern Uganda had the highest labour productivity of 7.04 kg/man-day, followed by Central Uganda (5.23 kg/man-day), Western Uganda (5.00 kg/man-day) and Northern Uganda (4.61 kg/man-day) [16]. Considering total labour in man-days, the study indicated Western Uganda as having more man-days (145.81 man-days) compared to Eastern Uganda's 101.72 man-days. Therefore, Western Uganda has the lowest labour productivity, but the study did not reveal the differences in labour productivity for adopters and non-adopters.

The response of maize output to the amount of seed depends on a number of factors; the most important ones being variety of the seed (whether improved or local), pest and diseases management and whether sorted or not [26]. Compared to improved seed, *Local* maize seed may not give high output due to their inability to respond to inputs such as fertilizers. However, most smallholder farmers complain of the higher cost of improved seed, little do they know that the higher initial cost is compensated by high yield and profit margin [7].

The recommended mean seed rate per acre is 10 kg [27]. However, this depends on whether it is pure or mixed stand. It also depends of the ecological conditions, method of planting and grain size. It was established by [28] that mean maize output obtained from improved seed as 2941.5 kg/ha per season which was significantly higher than those obtained from local seeds (1694 kg/ha per season). However, the study conducted in Eastern and Central Uganda, does not show the differences in output obtained within different improved maize varieties (i.e. *Longe* series and *Hybrid*). Another study done in Kenya by [17] found out that maize output had highest response to seed compared to fertilizer and labour. One additional kg of seeds increased maize output by 52kgs.

Most studies, such as [20], [18], [14] and [15] on multi-factor productivity, also known as returns to scale indicated that most maize farmers across the globe were experiencing increasing returns to scale. This indicates that they are operating in irrational zone I of the production function. Maize output would generally increase, if they increased input use proportionally.

This study was guided by the general objective of examining adoption of improved varieties and output response to inputs among smallholder maize farmers in Kabarole District Western Uganda. The specific objectives of the study were: to estimate and compare input elasticities of nitrogenous fertilizer, seeds, labour, plot size and herbicides for improved and local maize in Kabarole District and hence determine multi-factor productivity for improved and local maize. It was based on the hypothesis that the multi-factor productivity is higher for improved than local local maize.

2. Material and Methods

2.1. Theoretical Framework

Output response to input factors, known as total productivity is measured in terms of output per unit inputs. This can be obtained by estimating the Cobb-Douglas (C-D) production function among other approaches. The C-D production function was adopted in this study and has widely been used in agricultural studies, including that by [17], [16] and [29] and [18].

The production function describes the technical relationship that transforms inputs into outputs. It is part of micro-economic theory that deals with how a given set of inputs can be transformed into outputs, referred to as input-output relationship [30]. It is assumed that the farmers' main objective is to maximize profit by either increasing output, y or by minimizing the cost of inputs, x_i (e.g. cost of cultivating the land, cost of nitrogenous fertilizer, seeds, herbicides and paying labour) used to produce output $\boldsymbol{y_i}$. Cobb-Douglas (C-D) production function is one of the functional forms that can be used to estimate output response to inputs. Other functional forms include transcendental, quadratic and translog.

If the C-D production function contains two inputs, x_1 and x_2, its functional form is:

$$y = Ax_1^{\beta_1}x_2^{\beta_2} \tag{1}$$

where y is output, x_1 and x_2 are inputs, A embodies the manager's skill and other factors, while β are parameters representing elasticity.

From Equation 1, Marginal Physical Product (MPP) and Average Physical Product (APP) can be obtained as shown below:

$$MPP_{x_1} = \beta_1 A x_1^{\beta_1 - 1} x_2^{\beta_2} \tag{2}$$

$$APP_{x_1} = A x_1^{\beta_1 - 1} x_2^{\beta_2} \tag{3}$$

$$MPP_{x_2} = \beta_2 A x_1^{\beta_1} x_2^{\beta_2 - 1} \tag{4}$$

$$APP_{x_2} = A x_1^{\beta_1} x_2^{\beta_2 - 1} \tag{5}$$

$$MPP_{x_1}/APP_{x_1} = \epsilon_1 = \beta_1 \tag{6}$$

$$MPP_{x_2}/APP_{x_2} = \epsilon_2 = \beta_2 \tag{7}$$

Where ϵ_1 and ϵ_2 represent elasticities for inputs x_1 and x_2 respectively.

MPP refers to change in output as a result of using one additional unit of input and is calculated as $MPP_{x_j} = \frac{\partial y}{\partial x_j}$. This is known as first order condition of the production function. The second order condition is obtained by differentiating *MPP*, which is less than zero, indicating that when quantities of an input are increased indefinitely, while holding other factors constant, it will result in diminishing marginal productivity, where each additional unit of input results into lower output. This is calculated as: $\frac{\partial MPP_{x_j}}{\partial x_j} = \frac{\partial^2 y}{\partial {x_j}^2}$. *MPP* is obtained as a product of APP_{x_j} and elasticity (ϵ_j). *APP* on the other hand measures the level of farmers' efficiency which depends on the level of inputs used during the production process. It can also be obtained as follows: $APP_{x_j} = \frac{Output}{x_j} = \frac{y}{x_j}$[30].

The term *returns-to-scale* parameter also known as the *function coefficient or multi-factor productivity* refers to how output, y_i responds to the given levels of inputs, x_i and it is obtained by summing up the ratios of *MPP* and *APP* for each input. Therefore,

$$\varepsilon_j = \epsilon_1 + \epsilon_2$$
$$= \beta_1 + \beta_2$$
$$= MPP_{x_1}/APP_{x_1} + MPP_{x_2}/APP_{x_2} \tag{8}$$

where ε is the *returns-to-scale* or *multi-factor productivity* and j stands for input quantities, and x for input type

If the production function is homogeneous of degree n, and all inputs are represented in the production function, then the parameter representing the *returns-to-scale coefficient* is the *degree of homogeneity*. For a multiplicative power production function with j inputs, the *degree of homogeneity* and *returns-to-scale* are determined by summing up the j respective β coefficients which are elasticities of production for individual inputs. And, even if the production function is not homogeneous, *returns-to-scale* can still be determined by summing up the respective ratios of *MPP* and *APP* [30].

Returns-to-scale can be categorized into three: *increasing, decreasing* and *constant.* If $\sum \beta_j = 1$, then the production function exhibits *constant returns-to-scale*, if $\sum \beta_j > 1$ the production function shows *increasing returns-to-scale*, while if, $\sum \beta_j < 1$, the production function shows *decreasing returns-to-scale* coefficients.

The study applied a C-D production function because it is preferred when three or more independent variables are involved. In a C-D model, all inputs and outputs can easily be expressed in a log form and interpreted using most data analysis software [30]. It is also less affected by problems such as degrees of freedom and multicollinearity [31] and [32].

2.2. Empirical Model

The C-D production function used to estimate maize output response to inputs is specified as shown in equation 9:

$$OUTPUT = A\left[PLT^{\beta 1}FERT^{\beta 2}SEED^{\beta 3}LBR^{\beta 4}HERB^{\beta 5}\right] \tag{9}$$

The production function can be linearized as shown below:

$$\ln OUTPUT_i = \ln A + \beta_1 \ln PLT_i + \beta_2 \ln FERT_i + \beta_3 \ln SEED_i + \beta_4 \ln LBR_i + \beta_5 \ln HERB_i \tag{10}$$

where *ln* is the natural logarithm and *i* is the household. *A* is the coefficient parameter that embodies the managers' skill and other factors affecting the combination of inputs during production and $\beta$are coefficients representing elasticity estimated.

2.3. Description of Variables

Maize output *(OUTPUT)* is the dependent variable for the total maize grain harvested by the farmer during the September 2012-January 2013 planting season. More increase in output is expected with increase in quantities of inputs used by adopters than non-adopters.

Plot size (PLT) is the proportion of land (ha) a household allocated to maize (whether improved or local) during the September 2012-January 2013 growing season. In this study, maize output is expected to be positively correlated with plot size because, compared to small-scale farmers, large maize producers plant improved varieties and practice good management to avert uncertainties and risks involved with the new technology, since farmers do not have adequate information about it.

Nitrogen fertilizer (FERT) (Kg) mainly urea, CAN and DAP are commonly applied to boost maize productivity. Most studies, including that of [20] and [6], have confirmed low fertilizer use on most farmsdue to financial and accessibility constraints. Therefore, there is loss of soil fertility which results into low output. A positive relationship between FERT and maize output is expected in this study.

Seed quantity (SEED) refers to the amount of maize seeds (kg) planted by a household in a given plot. It is expected that output is positively correlated with a given quantity of seeds planted up to a level [e.g. 10 kg/ha as established by [27] and 18 kg/ha by [15], beyond which, any further increase[1] reduces output.

Labour (LBR) measured in man-days is included in this study because it is one of the primary factors of production. It is measured in man-days and disaggregated into family, social and hired habour. It is expected that maize response is higher for hired than family and social labour. This is because hiring labour is followed by strict supervision hence higher productivity.

Most studies, including that by [16] and [15] aggregate herbicides, fungicides and insecticides into agro-chemicals and study it as one variable. However, herbicides (HERB) (litres) applied by the household is isolated in this study, as the most important factor in controlling weed growth in the early growth of maize. Herbicide use is expected to improve maize output.

2.4. Study Area

The study was conducted in Kabarole District which is located in the western region of Uganda. The district has a total area of 8,318.2 sq. km with a relatively large human population of about 359,180 persons. The biggest district's population is rural oriented leaving only about 11 percent as urban and peri-urban dwellers. Averagely, the district has sizeable families of about 5.08 persons which in an indicator of potential labour and market supply for maize output and maize products [33].

Administratively, Kabarole District is made up of three counties of Burahya, Bunyangabu and Fort portal municipality. With its location in the banana-coffee system, the district is endowed with black fertile volcanic soils, which is a credit to increased maize production [5]. The district also lies at an altitude of 3,556 metres above sea level. It receives a bimodal rainfall of about 750-1000 mm annually necessary for increased maize production. However, the crop's productivity in the district and western region in general is low, estimated at 1.86t/ha compared to nationalaverage (1.94 t/ha) and potential yield of 7.5 t/ha per season as indicated in the study by [16].

The reason for selecting maize crop and Kabarole District was because it is the fourth largest producer of maize crop in Uganda next to Soroti, Mubende and Iganga in the year 2009 [34] and the first in western region. Yet they are growing maize markets in the western region emerging from refugee camps, Democratic Republic of Congo (DRC) and South Sudan. Agriculture being the main economic activity in the district is dominated by the production of maize and banana crops. However, banana crop has been severely hit by Banana Bacterial Wilt disease, suggesting that maize is likely to be the main source of rural livelihood support for both the local people and outsiders [35]. The district's animal enterprise diversity such as cattle, pigs, goats, sheep and poultry can be a source of manure to for improving fertility in maize plots [16].

2.5. Sample Sizeand the Data

Multi-stage sampling was conducted to obtain a total sample of 160 maize farmers, whereby, in the first stage, purposive sampling was used to obtain four sub-counties (Rwimi and Kibiito from Bunyangabu County and Ruteteand Kasenda from Burahya County. The area selected is the major maize producer in the district [35]. Four villages were further randomly selected from each sub-county making a total of 16 villages. Ten households were also randomly selected from each village in the last stage, being assisted by the list containing maize growing households obtained from respective area local council chairpersons.

Primary data were collected in the survey using a pre-tested questionnaire. It covered information about the type of maize planted (improved or local) and production information included plot size, type of labour used, nitrogen fertilizer use, herbicide use, variety of maize planted and source, maize yield, income obtained from on- and off-farm.

3. Results and Discussion

3.1. General Descriptive Analysis

Table 1 shows descriptive statistics on input factors used in maize production in the study area. On average, each maize farmer had 1.44 ha of land under maize crop and mean seed rate was 11.98 kg/ha/season, slightly above 10 kg/ha found by [27] and [17] but below that discovered by [15]. Only three point one (3.1) percent farmers applied nitrogen fertilizer and about 10 percent farmers used herbicides due to accessibility and capital constraints cited during the survey. It is argued in the study by [36], that adopters of improved maize in Norway always applied more fertilizers than non-adopters. Finally, every farmer at least used 36.8 man-days of labour for growing maize during the September 2012-January 2013 growing season. The average labour (man-days) is slightly above that of Western Uganda[2] (35.25 man-days) as established by [16].

1 It isexpected that when more and more seed quantities are planted in a fixed plot size, e.g. $\frac{d^2\text{Output}_i}{d\text{SEED}^2}$, it results into less output than the previous indicating a negative marginal productivity slope. This is beyond this study.

2 The study by [8] established that 35.25 man-days/ season were used for maize production in Western Uganda but did not include Kabarole District.

Table 1. *Input factors for adopters and non-adopters of improved maize*

Variable	Adopters n=(35)		Non-adopters (n=125)		Total (N=160)		Sig
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. Dev.	
Fertilizer (kg)	25.06	35.25	0.69	1.05	10.44	22.13	0.678
Herbicide (ltrs)	3.00	1.05	2.50	2.07	2.81	1.47	0.060
Labour (man-days)	37.91	21.77	36.31	18.76	36.77	19.32	0.122
Seed (kg)	16.29	11.20	10.38	6.83	11.98	9.15	0.055
Plot (ha)	2.03	1.21	1.26	0.73	1.44	0.91	0.005

Table 1 further show that adopters had a comparative advantage in terms of inputs compared to non-adopters. There was also a significant difference in the means, for herbicide, seed and plot size between adopters and non-adopters.

3.2. Input Elasticities for Adopters and Non-adopters (Cobb-Douglas Model/Analysis)

This section presents results of the Cobb-Douglas production function estimation showing input elasticities. Table 2 shows the input elasticity of labour, plot size, seeds, nitrogen fertilizers and herbicides. The elasticities of various types of maize seed planted as well as labour categories employed during production are also examined here. Most input coefficients are positive and significant, indicating that a one percent increase in the use of each input increases maize output by a certain percentage.

Table 2. *Input elasticity for all inputs, seed and labour type.*

Dependent Variable: ln Output.

Input variable	β_i for adopters	β_i for non-adopters	β_i for Average
All inputs			
lnPlot (ha)	1.72***	1.66***	1.70***
lnFertilizer (kg)	1.17**	1.01	1.09**
lnSeed (kg)	1.54***	1.57***	1.54*
lnLabour (man-days)	1.20***	1.26***	1.09**
lnHerbicide (ltr)	2.82	1.51***	1.72
Multi-factor productivity	8.45	7.01	7.14
Seed input (kg)			
Local		1.00***	1.00***
Hybrid	1.01***		1.01***
Longe series	1.04***		1.05***
Labour input (man-days)			
Hired labour	1.42***	1.50***	1.47***
Family labour	1.58***	1.80*	1.41***
Social group	1.41	1.67	1.44***

*, ** and ***, means significant at 10, 5 and 1 percent respectively

A one percent increase in the plot sizewould increase maize output by one point seven two (1.72) percent for adopters, a one percent increase in nitrogen fertilizer use would increase maize output by one point zero nine (1.09) percent for both farmer-categories and a one percent increase in seed rate would increase output by one point five four (1.54) percent for both farmer-categories. A one percent increase in man-days would increase output by one point zero nine (1.09) percent and lastly, a one percent increase in herbicide use increases output by one point seven two (1.72) percent, *ceteris paribus*.

The study shows improved maize had the highest elasticity to plot size, fertilizers and herbicides, while yield would increase more significantly if non-adopters used more units of seeds and labour (Table 2). For all farmer-categories, there was low output response to fertilizers and labour. This is probably because most maize farmers do not apply the right type and quantity of fertilizer and at the right time as earlier established by [17]. Also, most farms in Africa use family labour whose productivity is low due to lack of timeliness in farm activities [37].

Table 2 further shows that maize response to all inputs considered is elastic, whereby a one percent increase in input use results into a more than one percent increase in outputfor all farmer-categories, with the exception of local seed which shows unit elasticity. However, there are variations in output response to inputs depending on whether farmers adopt or not. For example Summation of elasticities (exponents) of production with respect to every input for a *homogenous function* is 8.45, 7.01 and 7.14 for improved maize, local maize and average (all) respectively. This is also known as *returns-to-scale* coefficient/ total output elasticity/multi-factor productivity. It implies that maize output could improve by 8.45, 7.01 and 7.14 percent if all input factors are varied by one percent for adopters, non-adopters and all farmers (average) respectively. Based on this, one can accept the null hypothesis that improved maize has a higher multi-factor productivity than local maize.

In terms of output response to the type of maize seed, *Longe* series had the highest elasticity (β=1.02) followed by *Hybrid* (β=1.01) and *Local* maize seeds (β=1.00) (Table 2). Response of improved maize was slightly elastic compared to local, indicating a higher potential for increasing maize output through adoption of improved varieties.

Results also show that output was elastic for all labour-categories (Table 2). A one percent increase in man-days increases output by more than one percent. Output response to various categories of labour is not so different. This contradicts with apriori expectation, where it was suggested that a higher elasticity could be obtained from hired labour due to strict supervision.

Generally, response of output to seed and labour quantity was the same for both adopters and non-adopters. This is because in order to produce both improved and local maize, one needs to use the same quantities of labour and seeds. Adopters obtain higher maize output if they expand maize acreage; use more herbicide and fertilizer compared to non-adopters. However, high cost of opening land, purchasing herbicides and nitrogen fertilizer are the main limiting factors cited by the respondents. Any intervention, whether by government or private sector, that makes these inputs available to farmers increases maize output.

4. Conclusion

Maize output response to all inputs studied was elastic. The response was more elastic for adopters than non-adopters. The multi-factor productivity indicates *increasing returns-to-scale coefficient*for both adopters, suggesting the need to adopt other inputs together with improved varieties. Generally, the study showed that adoption of improved maize improves input elasticity and maize productivity.

This study recommends that, government and other development partners should not only subsidize improved maize seed but also other inputs such as fertilizers and herbicides. This is because increased maize productivity requires adoption of improved technologies a package.

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