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Fertilizer Use and Maize output in Sub-Saharan Africa: Empirical Evidence from Selected African Countries

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Abstract

Fertilizer consumption in Sub-Saharan Africa countries has been found to remain low as compared to countries in similar level in other parts of the world. This has led to stagnation and declined yields in most crops across parts of Sub-Saharan Africa for several decades while that in countries that have increased fertilizer use have seen their agricultural productivity considerably increased over the years. This paper examines the effect of fertilizer use on maize output in selected African countries for the period 1990-2010 using data on fertilizer application rates. The data was analyzed using fixed effects regression based on a Cobb-Douglas production function. To take care of country differences in terms of production environments, country dummies were used in the fixed effects estimation. Empirical results indicated that maize output was positively and significantly correlated with land, labour, rainfall, aggregate fertilizer use, nitrogen and phosphorous nutrient fertilizers with land and labour having the highest effect on maize output in Sub-Saharan Africa To take care of rainfall vulnerabilities that could easily negate the positive effect of rainfall, supplementary irrigation measures should be put in place which could include rain water harvesting and small-scale water storage among maize producing households. Given the indication that fertilizer use was low despite its positive influence in maize output, it is recommended that strategies be put in place by relevant stakeholders in respective countries in a bid to boost aggregate and nutrient fertilizer use so as to further increase maize output and these could include price reduction strategies like subsidies and timely availability of fertilizer, reduction in import fee, clearance and warehouse charges at the ports of entry as a way of reducing the final market price. It could also be necessary for creation of more awareness among maize producers on the importance of adequate fertilizer use especially through agricultural extension workers and other relevant stakeholders.

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1. INTRODUCTION

Previous studies have found that fertilizer use in most Sub-Saharan Africa (SSA) countries is notably low as compared to other developing countries. The studies show that SSA farmers use an average of about 9kg of fertilizer per hectare (ha) while farmers in Latin America use about 73kg in Latin America and those in Asia use about 100-135kg (Marenya and Barret, 2009). This low use is despite the fact that fertilizer is crucial in increasing crop output. For instance, Morris et al. (2007) notes that the low use in fertilizer in the region has seen declined crop output in the region while countries that increased fertilizer use have seen increased productivity over the years. Agriculture continues to be the backbone of most of the SSA countries and due to this fact, most countries have come up with policies and programs geared towards increasing fertilizer use in recent decades. Despite these interventions, fertilizer use still continues being with a number of supply side and demand side constraints being identified as being responsible for the low use at the regional and country level. These factors continue to limit the development of input markets and fertilizer uptake in the region. Bump et al. (2011) notes that the supply side constraints include lack of competition among suppliers and distributors in the countries or regions, poor dealer networks that result in late or irregular delivery and high transportation costs due to lack of adequate infrastructure. Hernandez and Torero (2013) indicate that uncertain policy environment and weak regulatory systems, a lack of market information and limited access to finance are also responsible for low fertilizer use. Ogeto and Jiong (2019) in their study on fertilizer underuse in SSA countries with a focus on the effect of international fertilizer price on fertilizer use found that fertilizer use was being negatively influenced by world fertilizer price and rainfall vulnerability in the region, an indication that besides the factors identified by Bump et al. (2011) and Hernandez and Torero (2013), fertilizer price both domestic and in the world market could be responsible for its low use in the region.

Fertilizer use has further been found to raise agricultural yields even though this differs from one country to another as found by a number of experimental farms. For instance, Duflo et al. (2008) found that fertilizer and hybrid seed increased maize yields from about 40 percent to 100 percent based on results from their experimental farms. However, Bationo et al. (1992) in a study on millet production, found that response to fertilizer use depended on other factors especially rainfall and crop planting densities and acknowledged that fertilizer use had large benefits to farmers during favourable conditions. Beaman et al. (2013) also notes that Africa's fertilizer rates and yields are generally lower compared to other regions and that a large gap exists in between Africa and the rest of the world in cereals such as Maize. Kouka et al. (1995) and Poulton et al. (2006) further observe that the low fertilizer usa has contributed a decline in per capita agricultural production over time in the recent decades hence making fertilize underuse more prevalent than fertilizer overuse in most of SSA countries. It has further been found that farmers who use fertilizer in the region have been found to be using it inconsistently with majority of them switching between using and not using fertilizer from one season to another.

On the contrary other studies have shown that the overall income gain to fertilizer is reasonably substantial and that farmers who use fertilizer have a higher income return than those who don't use fertilizer (Duflo. 2011). However, Duflo (2011) further observes that it is possible that the absolute income gain from fertilizer use is not make it worthwhile if there is a significant cost in using it even if the returns are high. His study observes that the costs associated to fertilizer use could be the time and money spent to the market in search for fertilizer and time spent in learning how to use the it. To ensure this intensive use, Beaman (2013) observes that farmers should be provide with fertilizer in time as this dramatically increases the quantity of fertilizer used an indication that free access to fertilizer increases the effect on use. This is due to the fact that an expenditure on fertilizer affects the expenditure on other inputs. From findings by a number of previous studies there it has been found that fertilizer use plays a key role in crop productivity but its use in SSA countries though being indicated to be low, empirically this has not been studied to establish the actually effect on its use. This study therefore focused on trying to find out how fertilizer use besides other inputs were impacting maize output using a selected number of African countries based on availability of data on fertilizer use in maize.

2. LITERATURE REVIEW

Fertilizer use has been found to play a productivity enhancing role with an observed increase in yields when fertilizer use was increased appropriately even though this has not been without counter arguments. For instance, Folberth et al. (2013) conducted a study on modeling maize yield response to improvement in nutrient, water and cultivar inputs in sub-Saharan Africa using a bio-physical model to estimate plant growth and crop yield at a daily time. The study used site specific data which were longitude, latitude, elevation, slope, soil properties, climate data, nitrogen and phosphorous fertilizer application and rain-fed maize cultivation areas rates among others. Downscaled observed daily climate data for the period 1901 to 2009 was obtained from the SLATE v1.1 database. Other data came from MIRCA2000 version 1.1 and FAOSTAT. The large-scale agricultural crop model GEPIC was used to stimulate maize yield response to different scenarios and the results showed that extension of irrigation and or planting of improved cultivars produced minimal effect on maize yield at the prevailing nitrogen (N) and phosphorous (P) fertilizer application rates. It was found that increasing nutrient supply to the levels similar to those in the high input regions could triple the maize yields and this greatly increased when improved cultivars were used. Use of irrigation was found to increase maize yields when combined with improved nutrient supply and cultivars. It was noted that the highest yields when combining the three best management practices were possible for East and Southern Africa but it could be costly to reach those levels.

Lambrecht et al. (2014) carried out an investigation to understand the process of agricultural technology adoption by carrying out a study on mineral fertilizer in eastern Democratic Republic of Congo in 2010/2011. The study covered two territories in the highlands of South Kivu, that is, Walungu and Kabare, a region that is extremely poor in an extremely poor country based on UNDP human development index ranking. The area is predominantly agricultural and highly populated. Data was obtained from qualitative interviews and discussions through a quantitative household survey and a complimentary village survey. Probit and Heckman estimation methods were used in the analysis. The study found that awareness about fertilizer was high in the region at 57 percent and was mainly influenced by education and social capital. It was also found that tryout was low at 13 percent of aware farmers but positively influenced by extension interventions and that continued adoption was high at 70 percent of tryout farmers but was determined by capital constraints and that not all extension interventions were effective for continued adoption. Vanlauwe et al (2014) investigated conservation agriculture in Sub-Saharan Agriculture with a focus defining the appropriate use of fertilizer in order to enhance crop productivity. The explored a fourth principle in defining conservation agriculture besides soil surface cover, minimum tillage, and diversified crop rotations. The analysis found that appropriate use of fertilizer resulted in substantial increase in crop output and crop residues. The findings suggested that crop output in SSA would benefit considerably from fertilizer adoption which would in turn lead to high availability of crop residues. These residues could allow alternative uses and at the same time retaining minimal requirements for use as soil cover. The study concluded that strategies a fourth principle of appropriate fertilizer use in SSA should include conservation agriculture so as to increase the likelihood of benefits of fertilizer use to smallholder farmers.

In a study in Ethiopia, Yao (1996) examined the determinants of cereal productivity of the peasant farm sector covering the period 1981 to 1987 using a Cobb-Douglas production function. The aim was to estimate the effects of various inputs on cereal crop production which included teff, wheat, maize, barley and sorghum. The results of the study found out that 90 percent of the output was explained by land and labour while fertilizer use was found to explain 10 percent of the crop output. The results further found that rainfall was also a very important factor in cereal production with increase in rainfall increasing output tremendously. Kihara et al. (2016) carried out a study with the aim of understanding the variability in crop response to fertilizer and amendments in Sub-Saharan Africa. This study employed agronomic trials which were carried out with the intention of identifying soil fertility constraints in Kenya, Malawi, Nigeria, and Tanzania. The study covered 1 to 3 sites covered in each country in mainly agricultural areas. The field trials were conducted between 2009 and 2012 using data for 1 season in all sites except for one in Malawi where 2 seasons were used with a total of 310 trials being conducted in individual fields among the countries. The study found out that constraints to crop production were varying considerably even within a site and concluded that addressing the limitations in secondary and micronutrients in addition to increasing soil carbon can improve response to fertilizers. They further observed that for sustained crop production intensity in smallholder farming in SSA there was need to develop management strategies to improve fertilizer and other inputs use efficiency in addition to recognizing the site-specific response patterns.

Shehan and Barret (2016) carried out an evaluation on agricultural inputs use in SSA through a survey of farming households and a collection of data in Ethiopia in 2011.12, Malawi in 2010//11, Niger in 2011/12, Nigeria in 2010/11, Tanzania in 2010/11 and Uganda in 2010/11. The data collection only targeted those households that had cultivated at least one agricultural plot in the said periods. Accros the six countries, the sample included 22,565 cultivatating households and 62,387 agricultural plots, which represented nearly three quarters of all households in the full survey and was overwhelmingly rural. The data was analyzed using descriptive and regression analysis. The study came up with ten findings on input use in SSA which included: that modern input use was relatively low in aggregate but was not uniformly low across the countries under study and this was especially so for fertilizer and agro-chemicals; that mechanization and irrigation remained quite small; that there was considerable variation within countries in the prevalence of input use and of input use intensity conditional on input use; that there was suprisingly low correlation between the use of commonly paired modern inputs at household and plots level; that input intensification was happening and particularly for maize production; that an inverse relationship consistently existed between farm or plot size and input useintensity; that farmers did not significantly vary input application rates according to soil quality; that few households were using credit to purchase modern farm inputs; that gender differences in input use existed at the farm and plot levels; and that national level factors explained nearly

50 percent of the farm level variation in inorganic fertilizer and agro-chemical use. Sheahan et al. (2013) carried out a study to investigate whether Kenyan farmers were under-utilizing fertilizer and its implications for input intensification strategies and research. The study used data from Egerton University's Nationwide Tegemeo Rural Households Survey where households were asked a range of questions about their agricultural activities for the years 1997, 2000, 2004, 2007 and 2010. Standard proportional sampling using census data was used as the basis for extraction of the sample households majorly in the rural divisions of the country getting a total panel of 1243 households consistently interviewed out of the initial 1500 households. Both descriptive and regression methods were applied in the analysis. The study found fertilizer use at commercial prices to be profitable across a large proportion of Kenya's maize producing areas and that nitrogen application rates were consistently and steadily increasing towards risk-adjusted optimal levels over the survey years even though the estimated optimal levels were far below the government fertilizer recommendations. They noted that an increase in fertilizer use alone was not necessarily profitable in most farmer's fields in their current form and that it was necessary to supplement fertilizer use with complimentary inputs and by paying attention to soil conditions.

3. METHODOLOGY AND DATA

Data

The study used a national panel data for ten African countries including Egypt, Ethiopia, Guinea, Kenya, Malawi, South Africa, Togo, United Republic of Tanzania, Zambia and Zimbabwe for the period 1990 to 2010. The data on fertilizer application rate for maize by nutrient type per hectare was obtained from the Iowa State University website which had derived the rates based on data sourced from the International Fertilizer Association (IFA). Data on fertilizer input for maize was obtained by deriving the aggregate of nitrogen, phosphorous and potassium nutrients applied per hectare in each country by year by using the fertilizer application rates by nutrient type for maize. The data on area of maize harvested, yield and gross production quantity was obtained from FAOSTAT website. Data on maize seed quantity was also obtained from FAOSTAT. Data on the value of maize and the gross output value for all agricultural activities were obtained from FAOSTAT annual estimates. Data on labour input for maize was not readily available. To determine the labour input, we adopted the method adopted by Yao (1996) using data on labour participation in agricultural production per country from USDA Economic Research Service which was the most recent data. It was assumed that the share of labour used for maize crop was equal to its output value share to the total output values for all agricultural activities in respective countries. Mundlak et al. (2012) defines agricultural labour as the economically active population in agriculture and the study based its labour determination based on this definition. The following formula was used to derive the labour input for maize.

$N_{it} = LS_{it} * VS_{it}$

where N_{it} is the labour engaged in maize production in country *i* and year *t*, LS_{it} is the population economically engaged in agricultural production in country *i* and year *t* and VS_{it} is the share of maize output value to the total output value for all agricultural activities in country *i* and year *t*. VS_{it} is equivalent to the total value of maize over the gross output value of all agricultural activities in country *i* in year *t*. The gross output value is inclusive of the value of all crops and livestock in country *i* and year *t*.

Theoretical Model

This study was based on the theory of production based on the Cobb-Douglas production function which was used to explain the effect of fertilizer use on output of maize. The classical Cobb-Douglas production function theoretical model was used to estimate the inputs elasticity with respect to maize output. The major determinants in the Cobb-Douglas production function were land, labour and fertilizer. The specification of the model started with the basic Cobb-Douglas production function similarly as used by Yao (1996) given as:

$$Y_{it} = AH_{it}^{\alpha}N_{it}^{\beta}F_{it}^{\theta}e^{U_{it}} \quad \text{......} (1)$$

where $Y_{it}$is the output of maize in country *i* and year *t*, A is a constant term, $H_{it}$is the land area under maize in country *i* and year *t*, N_{it} is the labour used maize in country *i* and year *t*, F_{it} is the fertilizer used in maize in country *i* and year *t* and U_{it} is a error term. α, β and θ are the elasticities respectively for land, labour and fertilizer with respect to maize output. There were 10 countries and therefore j = 1, 2, …,10 and a total of 21 years, with t = 1, 2,……,21.

Taking logarithms on equation (1) we get,

$$lnY_{it} = C + \alpha lnH_{it} + \beta lnN_{it} + \theta lnF_{it} + U_{it} \quad \text{......} (2)$$

where C is a constant term, lnY_{it}, lnH_{it}, lnN_{it} and lnF_{it} are respectively the natural logarithms of Y_{it}, H_{it}, N_{it} and F_{it}.

Taking care of the effect of maize seed and rainfall changes, a measure of quantity of maize seed used (S) and annual rainfall (Pr) were used. Since fertilizer use and rainfall quantities were very small in comparison with other variables in the model, the two variables were included in the model in their natural forms.

Thus equation (2) can be rewritten as:

$$lnY_{it} = C_0 + \alpha lnH_{it} + \beta lnN_{it} + \rho lnS_{it} + \theta F_{it} + \gamma Pr_{it} + U_{it} \quad \text{......} (3)$$

Equation (3) explains the effects of land area, labour, maize seed aggregate fertilizer use, and rainfall on maize output. However, due to the different production conditions in different countries, a set of dummy variables were added into equation (3) to take care of country differences in maize production conditions. The model was also used to determine the effect of the individual nutrients on maize output in place of aggregate fertilizer.

$$lnY_{it} = C_0 + \alpha lnH_{it} + \beta lnN_{it} + \rho lnS_{it} + \theta F_{it} + \gamma Pr_{it} + \sum_{j=2}^{10} c_i D_i + U_{it} \quad \text{......} (4)$$

where Y_{it} is the physical output of maize in country *i* and year *t*, H_{it} is the land area for maize in country *i* and year *t*, N_{it} is the labour input in thousands for maize in country *i* and year *t* , S_{it} is the Quantity of maize seed in tonnes used in country *i* and year *t* , F_{it} is the aggregate fertilizer usage per hectare for maize in country *i* and year *t*, Pr_{it} is the annual rainfall in country *i* and year *t*, D*i* is a dummy variable for country *i* and c*i* is the difference between the intercept for country *i* and that for the first country and U_{it} is the error term. α, β, ρ, θ *and* γ are parameters of estimation. Equation 4 was also used to determine the effect of individual nutrient fertilizer, that is, nitrogen (Nit), phosphorous (Pho) and potassium (Pot), on maize output in place of aggregate fertilizer (F). Where: Nit is the quantity of nitrogen nutrient fertilizer used per ha in maize in country *i* and year *t;* Pho is the quantity of phosphorous nutrient fertilizer used in maize in country *i* and year *t;* Pot is the quantity of potassium nutrient fertilizer used per ha in maize in country *i* and year *t.*

Estimation Methods

Panel data was used in the investigation of the inputs influencing maize output in the ten selected African countries spanning the period between 1990 and 2010. Hausman test was used to confirm that fixed effects were preferred to random effects. Fixed effects with country dummies were used in estimating maize output response to factors of so as to take care of country differences in maize production and input use conditions. The study employed STATA in its analysis. For this study, the option robust was used in the Stata command during analysis so as to obtain heteroscedasticity-robust standard errors. The coefficients as presented in model one results were read directly as elasticities for three variables, that is, land, labour and quantity of maize seed, while that of fertilizer used and rainfall (precipitation) were read in unit form. The sign and significance of the coefficients indicate the direction of the impact by the independent variables on the dependent variable.

4. RESULTS AND DISCUSSION

This sub-section presents regression findings on the effect of factors of production, that is, land area under maize, labour, fertilizer use, maize seed used and precipitation, on maize output. Estimated results were obtained based on a Cobb-Douglas production function as in equation (4). To address any possible challenges of heteroscedasticity, robust was included in the Stata command when running the results using fixed effects regression with country dummies. The results were estimated after carrying out a Hausman test. The Hausman test had a prob>chi2 of 0.0000 implying that fixed effects estimations were preferred to random effects estimations. The results are as presented in Table 1 which presents elasticities of land, labour and maize seed with respect to maize output while fertilizer use and precipitation are presented in unit form.

The estimation in Table 1 generates consistent and expected results for all the variables and also indicates that the coefficients are different from zero. The R^2 value for the estimation is very high at .828 when using fixed effects in column 1 of Table 1, without country dummies and .98 when fixed effects with country dummies is used in columns 2 to column 6 as shown in Table 1 implying that over 98 percent of maize production is explained by the included independent variables in all the regressions. Column 2 provides the results of interest in maize output response to aggregate fertilizer use which is the key variable of interest in the regression. Columns 3, 4 and 5 present the results for maize output response to nitrogen, phosphorous and potassium nutrient fertilizers respectively while column 6 presents the results for maize output in response to simultaneous inclusion of all the three nutrients. From the estimation, the results show that maize output is mainly determined by land (H) and labour (N) but also positively and significantly influenced by aggregate fertilizer use, nitrogen and phosphorous nutrient fertilizers and rainfall (precipitation) as shown in Table 1. Though positively influenced by potassium nutrient fertilizer, the result is insignificant. The results are discussed as follows.

The elasticity of land is 0.224 which is positive and statistically significant at 0.01 significance level as shown in column 2. Ceteris paribus, this implies that an increase in the size of land under maize production by 1 percent leads to an increase in maize output by 0.224 percent. The coefficient of land is similarly positive and statistically significant in the results in column 3, 4, 5 and 6 with elasticities of 0.224, 0.158, 0.190 and 0.167 respectively implying that an increase in land under maize production by 1 percent increases maize output by 0.224, 0.158, 0.190 and 0.167 percent respectively a further confirmation of the positive influence of size of land on maize out. The results were in harmony with those of Yao (1996) and as expected given that if land size under maize production was expanded then this could mean an increase in overall maize plant population and this could lead to an increase in overall output of maize. This gives an overall indication that to increase gross maize output in the region, it is essential to put more land under maize. However, the increased output could equally be realized by optima use other inputs like fertilizer so as to spare more land for other production activities and increased soil cover through afforestation so as to mitigate the rainfall vulnerabilities reported earlier.

The labour (N) variable is positive and statistically significant at 0.01 significance level in all the regression results in all the columns with an elasticity of 0.999 in column 2 in Table 1. This implies that an increase in the amount of labour used in maize production by 1 percent increases maize output by 0.999 percent which is a very high response. Similarly, the labour coefficient in columns 3, 4, 5 and 6 all indicate a very high and positive maize output response to labour use with elasticities of 0.998, 1.000, 1.006 and 0.995 respectively an implication that an increase in labour by 1 percent saw an increase in maize output by 0.998, 1.000, 1.006 and 0.995 percent respectively. This is a further confirmation of the positive effect of labour on maize output in SSA. This result was as expected as an increase in labour could generally lead to an increase in maize output since maize husbandry management practices like planting, weeding and even harvesting and post-harvest practices could adequately be carried out and in good time. This is also given that maize production is SSA countries is largely labour intensive with minimal use of machinery and equipment as found by Koussebe and Nauges (2016) and Abubakar and Sule (2019) who argue that given the low availability and use of machinery, sufficient labour is necessary for increased maize output due to their high positive correlation.

The elasticity of maize seed (S) is not significant and negative in sign for all the results except in column 4. This gives an indication that maize seed quantity was not significantly influencing maize output with too much quantity in production leading to reduction in output. This finding is in harmony with the findings of Batino et al. (1992) who found a negative correlation between quantity of millet seed and millet output and that of Martey et al. (2019) who found a negative correlation between quantity of maize seed and maize output. This is as expected since high crop density will have a negative effect on overall output due to increased intra-crop competition for nutrients, sunlight and moisture which are all necessary for healthy crops. On the contrary, Abubakar and Sule (2019) find a positive correlation between maize output and maize seed but the study is silent on the quality of the seeds used. However, the results in column 4 indicated that an increase in quantity of seed required complimentary increase in phosphorous used even though the results were not significant and conclusive.

The contribution of aggregate fertilizer (F) to maize production is positive and significant at 0.05 significance level. The size of the coefficient in unit form is 0.00103 as shown in column 2 implying that an increase in fertilizer use by 1 unit per hectare increases maize output by 0.00103 percent. The result was as expected and in harmony with those of Yao (1996); Duflo et al. (2008) and Abubakar and Sule (2019) who found a positive correlation between fertilizer and maize output. The results confirm the importance of sufficient use of fertilizer in maize output which gives an indication that even though increase in acreage under maize positively contributed to increased maize output, increasing fertilizer use could help spare more land for other uses by increasing the overall yield and thus meeting the food needs in the region. On the influence of the individual nutrient fertilizers on maize output, only nitrogen (NIT) and phosphorous (Pho) nutrient fertilizers were found to be positively and statistically influencing maize output while potassium was found to be positive but insignificant. This was the same case when the individual nutrient variables were included in the regressions individually as shown in columns 3, 4 and 5, and when then nutrient variables were included in the regression simultaneously as shown in column 6. However, the results in column 6 had higher coefficient values as compared to when the nutrients were regressed separately an indication that column 6 had better results. The coefficient for nitrogen fertilizer in column 3 of Table 2 was 0.00141 at 0.01 significance level implying that an increase in the quantity of nitrogen fertilizer used in maize production by 1 unit led to an increase in maize output by 0.00141 percent. On the hand, the coefficient of nitrogen in column 6 was 0.00225 at 0.01 significance level implying that an increase in the quantity of nitrogen fertilizer used in maize production by 1 unit led to an increase in maize output by 0.00225 percent, a confirmation of a positive correlation between maize output and nitrogen fertilizer use. This result was as expected and in line with Folberth et al. (2013) given that in much of the maize production in SSA countries, the nitrogen component in the fertilizer used during planting was the highest and also given that in most of the countries farmers were doing top dressing with nitrogen fertilizer and given the productivity enhancing role of nitrogen, its increased used in production could positively contribute towards increased maize yield. Nitrogen fertilizer is also a highly water-soluble fertilizer and is easily lost through leaching unlike other nutrients and hence the necessity for its use in every production season and in adequate amounts.

Similarly, phosphorous fertilizer was found to positively influence maize output and this is in agreement to Folberth et al. (2016) who recommended increased use of phosphorous fertilizer in order to boost production but with an observation that the need for increased use varied from place to place. The coefficient of phosphorous fertilizer is 0.0121 and statistically significant at 0.05 significance level implying that an increase in phosphorous use by 1 unit could lead to an increase in output by 0.0121 percent. On the hand, the coefficient of phosphorous fertilizer in column 6 was 0.061 at 0.01 significance level implying that an increase in the quantity of phosphorous fertilizer used in maize production by 1 unit led to an increase in maize output by 0.0161 percent, a confirmation of the positive correlation between maize output and phosphorous fertilizer use. Phosphorous fertilizes similarly plays a productivity enhancing role like nitrogen and its increased use in production could positively contribute towards increased maize yield. This is as also observed that majority of the countries that had high nitrogen use were using relatively higher amounts of phosphorous indicating that the two could be more effective when used complimentarily as confirmed by the regression results in column 6 where the coefficients of the nutrient fertilizers were found to be higher than when the nutrient variables were regressed separately. On potassium fertilizer use, it was found to positively influence maize output but the result was insignificant. The coefficient of potassium fertilizer was 0.0058 though not statistically significant implying that an increase in potassium fertilizer use by 1 unit could lead to an increase in output by 0.0058 percent. On the hand, the coefficient of potassium fertilizer in column 6 was 0.00693 though not statistically significant implying that an increase in the quantity of potassium fertilizer used in maize production by 1 unit led to an increase in maize output by 0.00693 percent, a confirmation of the positive correlation between maize output and potassium fertilizer use even though the results were not significant. This insignificant result could have been due to the low use of potassium fertilizer as compared to the other nutrients in most of the countries under study, with some countries not using any potassium fertilizer in the entire duration under study. It was however noted that maize yield was much higher in countries that used more potassium fertilizer as compared to those that did not, an indication that increased use of potassium fertilizer could substantially lead to higher yields. Hence a reason enough to put intervention price mechanisms that will see an increase in use of potassium fertilizer so as to boost maize output in SSA. This is because potassium fertilizer was found to be the most expensive nutrient fertilizer as compared to nitrogen and phosphorous nutrient fertilizers, a possible reason for its low use. This is in harmony with Donovan (2013) who argues that farm operators in poor countries avoid using productivity enhancing intermediaries because doing so increased their consumption risk. Given the high poverty levels in the region, many farmers could be avoiding the use of sufficient quantities potassium fertilizer due to associated costs. This argument is further supported by Duflo et al. (2008) who argues that even if the returns to fertilizer are high, the absolute income gain from using fertilizer does not make it worthwhile if there are significant fixed costs in using the fertilizer. This is a very close scenario to the use of potassium fertilizer due to high associated costs.

Finally, rainfall (Pr) was found to have a positive and significant coefficient of 0.00356 at 0.01 significance level as shown in column 2. This implies that an increase in rainfall by 1 unit could increase maize output by 0.00356 percent. The coefficients in column 3, 4, 5 and 6, that is, 0.00358, 0.00364, 0.00354 and 0.00375 respectively, also indicated that rainfall generally has a positive effect on maize output with an increase in rainfall by 1 unit leading to an increase in maize output by 0.00358, 0.00364, 0.00354 and 0.00375 percent respectively, which is a further confirmation of the positive correlation between rainfall amount and maize output. The results were as expected with an indication that rain-fed maize production was vulnerable to weather conditions especially unpredictable and erratic droughts and the need for use of supplementary means of water like irrigation so as to maximize the positive effects on output. This finding is in harmony to that of Bationo et al. (1992) who found that crop response to fertilizer use depended on rainfall and planting density, an indication that if rainfall was timely and adequate, this could trigger adequate fertilizer use and uptake by the crops and this in turn could positively contribute towards increased maize yields.

Overall, the estimation results from Table 1 indicate that an increase in aggregate fertilizer use and all nutrient fertilizer's use in Sub-Saharan Africa has a positive correlation with maize output even though the results for potassium use are not statistically significant. A similar positive finding is observed on the three other inputs, that is, land, labour and rainfall. The results further indicate that a reduction in maize crop density is necessary to increase production and this could be achieved through a reduction in the amount of seed used so as to attain the right maize crop population per unit area and by ensuring that maize producers were using high quality seed. This could reduce competition for nutrients and boost high maize yields in return. However, even though the maize seed variable is not statistically significant it gave an indication that if the quantity of seed used increased then maize output could decline which is a plausible reason. There was no information however on the quality of maize seed used.

Table 1: Output response to factors of production

	(1)	(2)	(3)	(4)	(5)	(6)
	fe	agg	Nit	Pho	Pot	All nutrients
VARIABLES	lnY	lnY	lnY	lnY	lnY	lnY
lnH	0.224***	0.224***	0.224***	0.158**	0.190***	0.167**
	(0.0701)	(0.0690)	(0.0688)	(0.0674)	(0.0691)	(0.0695)
lnN	0.999***	0.999***	0.998***	1.000***	1.006***	0.995***
	(0.0486)	(0.0539)	(0.0533)	(0.0501)	(0.0550)	(0.0488)
lnS	-0.0410	-0.0410	-0.0409	0.0150	-0.0202	0.00994
	(0.0615)	(0.0757)	(0.0755)	(0.0618)	(0.0703)	(0.0608)
Pr	0.00356***	0.00356***	0.00358***	0.00364***	0.00354***	0.00375***
	(0.00117)	(0.00113)	(0.00113)	(0.00110)	(0.00113)	(0.00111)
F	0.00103**	0.00103**				
	(0.000424)	(0.000449)				
NIT			0.00141***			0.00225***
			(0.000488)			(0.000603)
Pho				0.0121**		0.0161***
				(0.00550)		(0.00520)
Pot					0.00558	0.00693
					(0.0114)	(0.0113)
Constant	5.453***	6.702***	6.566***	7.859***	7.466***	6.984***
	(0.647)	(0.681)	(0.652)	(0.631)	(0.690)	(0.615)
Country Dummy	No	Yes	Yes	Yes	Yes	Yes
Observations	210	210	210	210	210	210
R-squared	0.828	0.980	0.980	0.981	0.979	0.983
Number of ID	10					

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The study found that land, labour, rainfall, aggregate fertilizer use, nitrogen and phosphorous nutrient fertilizer use were positively and statistically significantly influencing maize output in SSA countries. Quantity of maize seed used in maize production was found to negatively influence maize output but it was not statistically significant. On the other hand, potassium fertilizer was found to positively influence output but the result was also not significant.

5. CONCLUSIONS AND RECOMMENDATIONS

Fertilizer use in crop production, especially maize, is of paramount importance and this is especially so in SSA countries where food insecurity has been a major concern for decades. Maize is an important cereal crop in SSA given that it is a staple food crop in most of Africa. To attain the food demand in SSA, increased production of maize and other cereals is the only solution to this and to attain food self-sufficiency fertilizer use in optimal and or in reasonable quantities in production is of necessity. From the findings of the study, it was concluded that land area under maize production, labour, rainfall, aggregate fertilizer use, nitrogen and phosphorous nutrient fertilizers were positively and significantly correlated with maize output in SSA. Of all the variables considered, land and labour were found to have the highest effect on maize output in SSA. Based on the above conclusion, it is recommended that more land and labour should be put into maize production so as to even further boost maize output in SSA countries. To take care of rainfall vulnerabilities that could easily negate the positive effect of rainfall on output, supplementary irrigation measures should be put in place which could include rain water harvesting and small-scale water storage among maize producing households. Given the indication that fertilizer use was low despite its positive influence in maize output, it is recommended that strategies be put in place by relevant stakeholders in respective countries in a bid to boost aggregate and nutrient fertilizer use so as to further increase maize output and these could include price reduction strategies like subsidies and timely availability of fertilizer. It could also be necessary for more awareness among maize producers on the importance of adequate fertilizer use especially through agricultural extension workers and other relevant stakeholders. Given the subsidy benefits that have been found to accrue in terms of increased fertilizer use and consequent increases in output, it is also recommended that domestic governments should seek financial assistance from foreign governments like The People's Republic of China and other big economies so as to run fertilizer subsidies in order to boost its consumption.

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