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Determinants of Yield Gap in Maize Production in Some Rural Communities of North West Nigeria

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Abstract
The study analyzed the yield gap and its determinants in maize production in northwestern Nigeria. A purposive sampling technique was used to collect primary data using a well-structured questionnaire from 100 maize farmers in the study area. Data were analyzed using descriptive statistics and multiple regression analysis. The result from descriptive statistics shows that the maize farmers had a mean age of 45 years, and were mostly males (89.0%). The maize farmers use an average of 63.1kg/ha of Urea and 65.1kg/ha of NPK. The mean quantity of herbicides and labour used by the farmers are 0.8litres and 20 man-hours respectively per hectare. The yield gap in Maize production ranges from 100-800kg/ha with a mean of 499kg/ha translating to about N42,500/ha loss of revenue. The socio-economic determinants of the yield gap are; labour, income from maize production, commercialization index and seed varieties were significant at ($p<0.005$) while only NPK fertilizer was significant at ($P<0.10$). The major constraints faced by the maize farmers are inadequate access to high-quality seed and inadequate fertilizer. The study recommended the provision of draught-resistant and high-yielding seed varieties of maize to bridge the yield gap.
Keywords: Maize, Yield-Gap, Fertilizer, seeds, and regression analysis

Introduction

According to Tilman *et al.* (2001), Sub-Saharan Africa will account for about half of the increase in the population of the world by 2050. On the other hand, the demand for agricultural products will continue to be on the increase. While food demand will increase by 50 % by 2050, feed grain demand for livestock will increase by 84% by 2020 (Delgado *et al*., 1999). Unfortunately, the yields achievable on farmers' fields might decrease or remain steady (Lovell *et al*., 2001). Globally, the yield gap for Wheat and Rice is about 36%, while in Maize; it is about 50% but up to 80% in Africa (Neumann *et al*., 2010). This situation implies that food shortages may exist or are likely to occur if appropriate measures are not taken. The options available to salvage the situation are for countries to; expand the cropped area cultivated, increase yields and reallocate current agricultural production to more productive uses (Licker *et al*., 2010). Yield gap analysis is gaining increasing attention globally. Estimating yield gaps shows the potential for sustainable intensification of Agricultural systems (Beza and Reidma, 2017). Agricultural productivity growth in Sub-Saharan Africa over the past four decades averaged only 2.4% compared with 4% in the rest of the developing world. The world continues to face the challenge of feeding the growing population, increasing average yields by reducing the yield gap has become imperative. As one would expect, there exists enormous heterogeneity in yields across Africa. The difference between farmers' yields and the world average is lowest in Southern Africa where over the past decade average cereal yields were 86% of that of the world average compared with Western, Eastern, and Central Africa where average yields were only 18%, 29%, and 35% of the world average. Maize is recognized as a major source of food and cash income among its predominantly small-holder farmers in Nigeria (Phillip, 2011). According to Fakorede *et al*., (2003), between 1980 and 2001, land area under maize crop cultivation increased significantly up to 40%. Maize is ranked as the most important cereal crop in sub-Saharan Africa. It provides food for more than 1.2 billion people in addition to other uses. Nigeria is the largest producer of Maize in Africa with an annual production of about 8 million metric tons (Babatunde *et al*, 2008). Maize is the third most widely grown crop in Nigeria and the crop is highly productive and less rigorous to produce.

De Datta (1981) defined the "yield gap" as the difference between yields on research stations and the actual yield on farmers' farms. On the other hand, according to Rimal and Kumar (2015), the yield gap is defined as the difference between the maximum attainable yield and the farm-level yield in a specific location. The

importance of yield gap analysis is well documented in the literature as it provides a measure of untapped food production capacity (Van Wart *et al*., 2013). The major pioneering work on yield gap analysis in Nigeria that included Maize was by Nwafor (2011). Several other studies on Maize conducted in Nigeria did not address yield gap analysis (Gani and Omonona, 2009; Awotide and Agbola, 2010; Zalkuwi *et al*., 2010; Obidi, 2011; Salau *et al*., 2012 and Sadiq *et al*., 2013). Furthermore, the average yield per hectare for Maize in Nigeria is as low as 1.50 Mt per hectare compared to the potential yield of 4 Mt per hectare (Valencia *et al*., 1999). However, the potential yield can be up to 5Metric tonnes or 5000 kg per hectare for Maize in Nigeria (World Bank, 2014; Nwafor, 2011; and NAERLS, 2011). The foregoing suggests that there is an information or knowledge gap on yield gaps for Maize. Secondly, a yield gap is obvious in Maize production in Nigeria. It is therefore imperative to study and understand this yield gap in terms of its magnitude and possible causes. This study therefore addressed the following objectives: described the socio-economic characteristics of Maize farmers in the study area; determined the input and output levels in Maize production; estimated the yield gap in Maize production; identified the determinants of yield gaps in Maize production and the production constraints in Maize production in the study area.

Yield gap analysis has been performed for several staple food crops in different regions. Analysis of yield gaps helps identify opportunities to improve crop yield and assess food security scenarios. The findings of the study will enhance the understanding of potential yield and yield gaps in Maize production which is very vital in identifying the opportunities for yield improvement in farmers' fields, especially in Northwestern Nigeria. Most importantly, the study will provide information on the pathways to raise Maize productivity sustainably as well as enhance resource use efficiency. The findings of the study can also be used for the formulation of policies that favour the adoption of yield gap-closing technologies for Maize production in Nigeria.

Methodology

The study was conducted in Katsina State northwestern Nigeria. It is an agrarian area in the northern Guinea savannah vegetation zone of Nigeria. It lies on the latitude and longitude 11° 32' N and 7° 19' E respectively. It has an average temperature of 32^{0}C and humidity of 44mm. The major occupation of the people there are crop farming, animal rearing and trading. Major crops grown in the area include cereals such as maize, sorghum and millet. The major ethnic groups in the study area are predominantly Hausa-Fulani, Igbo, Tiv, Igala, Gwari, Ibira and other Nigerian ethnic groups. Maize farming production is common among households in the study area. A purposive sampling technique was used in selecting five villages (Gardawa, Dukke, Ungwan Nabuka, Ungwan Shanu and Dan Fili) noted for Maize production in northwestern Nigeria. From each village, twenty (20) Maize farmers were randomly selected via a balloting method to give a total of 100 maize farmers for the study. Primary data was used for the study. The primary data was collected using a structural questionnaire to be administered by the researcher. Data was collected on respondent's socio-economic characteristics, quantity of input and output in maize production. Information on constraints in Maize production was also collected. Simple descriptive statistics were used in describing the socio-economic characteristics of the respondent, determine the input-output levels in maize production and identify the production constraints faced by maize farmers in the study area. The expression below was used to determine the Yield gap in Maize production

$YG = Yp - Ya$

Where:

YG= Yield Gap

Yp = Potential Maize yield per hectare in Nigeria (4Metric tons of 4000 kg) according to Valencia *et al* (1999)

Ya = Actual farm yield in kg per hectare realized by farmers on their fields

The Yield gap was converted to percentages for each Maize farmer, summed up and divided by the number of Maize farmers to obtain an average yield gap in percentage for the respondents. The expression

$\%YG = \frac{YG}{Yp} \times 100$ was used for the conversion to percentage.

Multiple regression analysis was used to identify the determinants of yield gaps. The model is shown below.

$Y=f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9) + u$ where:

Y= Yield gap in Kg

X_1= Age of maize farmers

X_2= Maize plots (Hectares)

X_3= Labor (Man-hour)

X_4= Farm income (Naira)

X_5= Quantity of herbicide (litres)

X_6= Quantity of NPK fertilizer (Kg)

X_7= Quantity of Urea fertilizer (Kg)

X_8= Commercialization Index (Monetary value of marketed output/Total quantity harvested)

X_9= Seed variety (1 if improved and 0 otherwise)

u = Error term

$1=370 Nigerian Naira

Results and Discussion

Socio-economic Characteristics of the Maize Farmers

The results in Table 1 revealed that 36.0% of the respondents were between 42-50 years of age, while the mean age of the respondents was 45 years. This indicates that maize farmers in the study area were dominated by young people who are active and fall within the productive age group. This result agrees with the findings of Ojoko *et al*. (2017), who reported that the majority of farmers (36%) that used climate-smart Agriculture to boost crop production (maize inclusive) were between the ages of 42-60 years, which forms the active years of the farmers and therefore, they are strong enough to engage in agricultural practices. Moreover, results further showed that the majority (89.0%) of the respondents were males; implying that there were more male maize farmers in the study area. This finding is similar to that of Olaniyi and Ismaila (2016) in southwestern Nigeria. The years of farming experience

of the respondents indicate that a large proportion of the respondents (35.0%) had between 1-10 years of maize production experience with a mean of 20 years. The result below implies that most of the respondents are well-experienced in maize production. Credit obtained was less than N60,000, while less than 50% of the respondents had no access to credit, market information and agricultural extension services. The usage of improved seeds is very common among the respondents.

Input and Output Levels in Maize Production

The result of the inputs and output levels among maize farmers in the study area is presented in Table 2.

The result shows that the quantity of Urea fertilizer used ranges from 20.0-120.0kg with a mean of 63.1kg/ hectare. For NPK fertilizer, the quantity used was between 15.0 and 190kg with a mean of 65.1kg per hectare. The number of herbicides used ranges from 0.4-1.8 litres with a mean of 08. litres and the majority of the farmers (60.0%) used between 06-1 litres. The result also shows that the number of pesticides used ranges from 0.7-1.2 litres with a mean of 0.6 litres. Moreover, the result showed that the maize farmers had labour in man-days hours that ranged from 16-25 hours with a mean of 20 hours.

Yield Gap Analysis in Maize Production

The result in Table 3 shows the yield gap in existing maize production in the study area. The yield gap was observed to range from 100kg - 800kg. The mean yield gap was however 499.0kg/ha. This represents about 12.47% of the potential yield of 4000kg/hectare for maize in Nigeria. However, this finding does not compare with that of Akintayo and Rahji (2011) and Akintayo, Rahji, Awoyemi and Adeoti (2011) who observed a yield gap of 51% and 52% for low land and upland Rice respectively in Nigeria. The difference could be due to the nature or type of crop studied and the production peculiarities of rice and maize. It can also be interpreted to mean that about five bags (100 kg bags) of maize are lost by farmers in the study area on a per-hectare basis. This quantity is quite alarming and it implies that there is a scope for increasing maize in the study area if the causes of the yield gap are identified and addressed. In Monetary terms, it means that about N42500 is lost as revenue per hectare by Maize farmers in the study area. This amount is quite high and can affect the living standard of Maize farmers in the study area and can equally lead to an increase in poverty levels.

Determinants of Yield Gap among Maize Farmers

The result of the regression analysis for the determinants of the yield gap among maize farmers in the study is presented in Table 4. The result shows that all the independent variables included in the model jointly and significantly influence or affect yield gap levels among Maize farmers. This is evident from the F value of 12.34 obtained. The F value was significant at ($p<0.05$). Similarly, the values of the adjusted coefficient of multiple determination show that the independent variables account for about 75% variable in the yield gap observed among the Maize farmers in the study area. This is an indication that the model has a good fit and can be used for further analysis. Furthermore, five of the nine independent variables included in the regression model are significant while the remaining four variables were not significant at ($p<0.10$). The following variables, labour, income from maize production, commercialization index and seed varieties were significant at ($p<0.005$) while only NPK fertilizer was significant at ($P<0.10$). In terms of the signs of the coefficients for the significant variables, only seed varieties had a positive sign for their coefficient. Babatunde, Salami and Muhammad (2017) reported that improved varieties will reduce the yield gap in irrigated rice cultivation. Improved varieties are superior to local ones and are also high-yielding as well as disease and pest-resistant. Asekenye *et al* (2013) also pointed out that the type of crop variety is significant in determining the yield gap in groundnut production. The result further shows that an increase in labour, income from maize production, commercialization index and NPK fertilizer will lead to a reduction in the yield gap. Elum and Sekar (2015) however observed that Nitrogen fertilizer is significant in yield gap reduction. Nitrogen is an essential nutrient required by crops for proper growth and development and subsequently, a yield gap reduction.

Production Constraints in Maize Production

The results of constraints faced by the respondents are presented in Table 5. The result shows that Maize farmers in the study area are facing numerous challenges which could lead to a reduction in yield and which will further expand the yield gap for maize in the study area. The major constraint facing the farmers is the inadequate access to high-quality seed. This was pointed out by about 95% of the respondents. The respondents pointed out that they have to approach government agencies to obtain seeds for planting and they often get small quantities that may not meet their needs. Furthermore, the second major constraint was inadequate fertilizer. The respondents pointed out that during the E-wallet or Growth enhancement scheme (GES) they were sure of getting at least a bag but now with the absence of the program fertilizers are quite expensive and not often available. Finally, the third major constraint is the poor condition of their soil which has lost its fertility and may not support crop production without the use of either organic and inorganic fertilizers or soil amendments. Nkonya, Pender and Oni (2009) also pointed out that low sol productivity or productivity hinders all year round Maize production in Nigeria. Other constraints include the high cost of inputs and unpredictable rainfall. Opaluwa, Ali and Ukwuteno (2015) in a study on the perception of constraints in north-central Nigeria equally made similar findings. However, the study does not agree with a more recent study by Girei, Saingbe, Ohen, and Umar (2018) which showed that the problems militating against maize production in in north central Nigeria were high cost of labour, pests and diseases and inadequate storage

facilities.

Conclusion

A yield gap exists in maize production in the study area. Furthermore, the major socio-economic factors that can reduce the yield gap in Maize are the commercialization index, income from maize, use of improved varieties and adequate farm labour. On the other hand, numerous constraints such as inadequate access to improved seeds and fertilizer as well as poor soil conditions are capable of further increasing the yield gap in Maize production in the study area.

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Table 1: Socio-economic Characteristics of the Maize Farmers

Characteristics	Frequency	Percentage	Minimum	Maximum	Mean
Age (Years)					
24-32	10	10.0	24	67	45.37
33-41	24	24.0			
42-50	36	36.0			
51-59	20	20.0			
60-68	10	10.0			
Years of Membership of the Association					
1-10	26	26.0	1	25	6.68
11-20	15	15.0			
>20	10	10.0			
Amount of Credit Obtained					
<60000	21	21.0	60000	500000	132850.0
60000-100000	20	20.0			
100001-150000	10	10.0			
150001-200000	15	15.0			
>200000	10	10.0			
Farming Experience					
1-10	35	35	3	40	20.05
11-20	19	19			
21-30	20	20			
31-40	26	26			
Number of Maize Plot					
1-2	29	29.0	1	6	2.11

3-4	31	31.0
5-6	40	40.0
Gender		
Male	89	89.0
Female	11	11.0
Membership of Association		
Yes	51	51.0
No	49	49.0
Contact with an Extension agent		
Yes	65	65.0
No	35	35.0
Access to Market Information		
Yes	85	85.0
No	15	15.0
Access to Credit		
Yes	56	56.0
No	44	44.0
Maize Variety		
Yes	95	95.0
No	5	5.0
Major Occupation		
Farmers	80	80.0
Traders	10	10.0
Civil servants	10	10.0
Total	100	100

Table 2: Distribution of the Respondents According to Inputs Level in Maize Production

Variables	Frequency	Percentage	Minimum	Maximum	Mean
Quantity of Urea					
20.0-70.0	85	85.0	200	1200	631.00
>70.0	15	15.0			
Quantity of NPK					
<50	46	46.0	150	1900	651.50
50-100	39	39.0			
100-150	10	10.0			
>150	5	5.0			
Quantity of Herbicides					
0.1-0.5	16	16.0	4	18	8.57
0.6-1.0	60	60.0			
1.1-20	24	24.0			
Quantity of Pesticides					
0.1-0.69	44	44.0	2	22	6.58
0.7-1.2	26	26.0			
>1.2	30	30.0			
Labour in Man-days hour					
1-10	5	5.0	16	25	20.56
11-20	41	41.0			
21-30	54	54.0			
Total	100	100			

Table 3: Distribution of the Respondent based on Yield Gap

Yield Gap(Kg)	Frequency	Percentage	Minimum	Maximum	Mean
100-400	44	44.0	100	800	499.00
>400	56	56.0			

Table 4: Determinants of Yield Gap in Maize Production

Variables	**Coefficients**	**Std. Error**	**t-value**
Constant	4031.571	446.958	9.020
X1 (age)	-2.219	1.984	-1.118
X2 (Maize plot)	6.197	12.791	.484
X3 (labor)	-33.709***	9.815	-3.435
X4(income)	-.008***	.001	-10.803
X5(herbicide)	-.007	.007	-.932
X6 (NPK fertilizer)	-.153*	.084	-1.818
X7 (Urea fertilizer)	-.124	.140	-.884
X8 (commercialization Index	-972.194***	258.778	-3.757
X9(Seed variety)	422.700***	97.342	4.342

Adjusted $R^2 = 0.75$ F Value 12.34 *** **=significance at 1% ***=significance at 5% *=significance at 10%

Table 5: Distribution of Respondent According to Constraints to Maize Farmers.

Constraints	**Frequency**	**Percentage**	**Ranking**
Inadequate access to high-quality seed	95	95	1st
Inadequate fertilizer	90	90	2nd
Poor soil fertility	82	82	3rd
Ineffectiveness of pest and disease control	75	75	4th
Scarcity of input	61	61	5th
High cost of inputs	53	53	6th
Unpredictable rainfall distribution	45	45	7th
Inadequate market	36	36	8th
Inadequate extension services	28	28	9th
Inadequate capital	25	25	10th
Low output prices	23	23	11th

Source: field survey, (2019) **Multiple responses allowed*