Effects of Fertilizer use on Potato Production in Western Rwanda

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Abstract

This study analysed the effects of fertilizer use on potato production in Kabatwa Sector, Nyabihu District, in Western Rwanda. Data were collected among 100 potato growers randomly selected in Kabatwa sector for the season 2014B. A well structured questionnaire was distributed in August 2014, and required information about the respondent's identification, fertilizer use, potato production and related constraints. The paired-samples T-test was used for data analysis. The results show that fertilizers have positive effects on potato output. The results from the paired-samples t-test show that the difference between the average crop production after and the average crop production before the adoption of fertilizers in the study area (1,155 kgs) is statistically different from zero following that the corresponding p-value (labelled Sig. 2-tailed) is smaller than 0.05. Accordingly, there has been a statistically significant difference between the potato output level comparing before and after fertilizer use in the study area. It was recommended that the Government should enhance fertilizer accessibility through credit facility to farmers, facilitate access to proximity extension services and encourage farmers to group into cooperatives.

Key words: fertilizer use, potato production, paired-samples T-test, Rwanda

JEL Classification Codes: D60; O13; O18; Q13; R20

1. Introduction

The need to meet ever increasing nutrition demands of the expanding human populations makes sustainable agriculture and agro-based sectors a front burner environmental and social development issue in sub-Saharan Africa. Food security concerns are currently escalating in sub-Saharan Africa (SSA) due to poor soil management practices on the fragile soils (Omotayo & Chukwuka, 2009).

Rwanda is a country with a population density estimated at 416 people per square kilometer (NISR, 2012) with 16.7% of the population staying in urban areas, while 83.3% stays in the rural areas. In addition, sixty percent (60%) of the population is below the poverty line. Like other countries in the region which have suffered years of intense conflict, Rwanda's economy has been virtually destroyed. Ethnic conflicts have erupted several times since 1990 culminating in deaths of hundred thousands of citizens in 1994.

Rwandan economy is in a quasi-exclusive dependence on agriculture with 91.1% of the population engaged in mainly subsistence agriculture, especially women. This sector contributes to 36% of the GDP besides contributing to about 70% of the country's export revenue. Land resource has been considered the most important factor of production, backbone of the economy and the basis of survival for the entire population generating about 90% of food stuffs required in the country. The population growth of Rwanda is already threatening the position of agriculture as the backbone of the economy and the basic source of livelihood (MINAGRI, 2009).

Consequent to the Genocide against the Tutsis in 1994, the country was almost entirely dependent on emergency grants and a post-conflict reconstruction plan financed by international donors. In 1998, the government agreed on an Enhanced Structural Adjustment Facility and, with the onset of relative peace, the economy has improved to some extent (Bingen and Munyankusi, 2002). Whereas Rwanda agriculture has seen growth in the recent past, the 2010 Government of Rwanda (GoR) leadership retreat asserted that "Agriculture is not fulfilling its potential for increasing the gross domestic product (GDP) and reducing the trade deficit".

Thus it is imperative to understand the need for enhancing sustainability of agricultural practices if agriculture is going to fulfill its potential for increasing GDP. Enhancing agricultural productivity and preventing food insecurity in Rwanda will rely on incorporating environmental sustainability interventions into the planning process to ensure that investments are adequately allocated to address environmental priorities within the relevant sectors.

For these reasons, it is very important to evaluate agricultural policies in developing countries from a sustainability perspective. The recent Crop Intensification Program (CIP) policy in Rwanda is aimed at boosting agricultural productivity through an improvement of productive inputs use, irrigation coverage and soil quality. Large improvements in the productivity of food crops are required to support the growing rural and urban population in Rwanda (Cantore, 2011). Productivity is a function of the usage of improved inputs such as seeds, fertilizers, water and machineries. Owing to the limited land resources and the effects of demographic pressure on land, the intensification of existing production systems becomes a tangible approach for increasing food production in the country (Cantore, 2011). Nutrients are very important for plant growth, crop farming and production of safe food stuffs, especially when organic and chemical fertilizers are combined (Chen, 2006).

Globally, while enhancing crop production, the Green Revolution proved to be unsustainable as it damaged the environment, caused dramatic loss of biodiversity and associated traditional knowledge, favored wealthier farmers, and left many poor farmers deeper in debt (Altieri, 2009). In the face of such global trends, the concepts of food sovereignty and ecologically based production systems have gained much attention in the last two decades (Altieri, 2009).

Maintaining and improving soil quality is crucial if agricultural productivity and environmental quality are to be sustained for future generations (Reeves, 1997). The productivity of the soil is largely determined by its fertility, which in turn is dependent on rootable soil depth and the nutrients stored in its mineral and organic constituents (Vlek et al., 1997).

Productivity gains with an increase in the soil organic carbon (SOC) pool are large, especially when combined with judicious input of fertilizers, irrigation and other amendments (Lal, 2006). The indirect effects of fertilization practices acting through changes in the nutrient composition of the crop have been reported to influence plant resistance to many insect pests (Altieri & Nicholls, 2003).

The recent efforts made in Rwanda by the Ministry of Agriculture and Animal Resources (MINAGRI) under a flagship of Crop Intensification Program (CIP) have revealed the potential of achieving food security. The subsidized low prices of inputs and the facilitation of supplying inputs through the program have eased the access to inputs by farmers across all areas of the country. To ensure that the accessibility will prevail in the absence of such interventions, it is important to elicit a genuine demand for the inputs from the farmers. The demand for inputs shall be raised by convincing the smallholder farmers through demonstrations of the profitability of their use and through aggressive extension services. Wider distribution networks that would reach the far remote areas are critical for increasing the use of fertilizers (Cantore, 2011).

This paper attempts to assess the contribution of fertilizer adoption to potato production in rural areas of Rwanda. More specifically, this study aims to analyze the effects of fertilizer application to potato cropping and farmers' livelihood in Kabatwa Sector, Nyabihu District, Western Rwanda.

2. Literature Review

Fertilizer adoption and food security in the world

According to Lok Sanjh Foundation (2007), manufactured fertilizers were introduced to European agriculture in the middle of the 19th century, after the discovery of the principles of plant nutrition. In the 1830's, it was discovered that minerals like nitrogen, phosphorus and potassium were plant nutrients. The scientist reprted that these mineral plant nutrients originated from mineralized plant residues and other organic soil materials. It was concluded that a deficiency of any single nutrient was enough to limit crop yield.

The value of fertilizers was demonstrated in the world's first agricultural field trials at Rothamsted in the UK. These trials continue to provide valuable information in fertilizer efficiency, with the long term trial on the Broadbalk site in continuous existence since 1856. Jia (2009) points out that enhancing agricultural productivity in developing countries is crucial to ease the tension of increased population and haunting concern on food security. In contrast, IRIN (2010) observes that farmers in Nepal face acute shortage fertilizers, which may impair food security programs; a similar situation is in Nigeria and other African countries.

However, CTA (2000) states that despite the huge amounts of public funds from internal sources invested to increase productivity levels through improved product and processing technologies, sluggish growth in many countries still persists. Similarly, scientists have made more in-depth studies on most areas of food and agriculture to alert farmers, governments, policymakers, industries and financial houses and donor agencies to engage in food production to avert crisis of hunger and malnutrition. Bassey (2002) maintains that intensive vegetable farming by women in Calabar urban in the southeastern zone of Nigeria is associated with food security measures for their households. Given their importance, it implies that reducing the use of fertilizers may result in a threat to food security. To enhance increase in the utilization of fertilizers by the rural farmers and therefore ensure food security, the following measures are pertinent.

The role of fertilizers in crop production

All plants need nutrients for growth. They must obtain these nutrients from the soil or other medium in which they're growing. Gardeners can also provide supplemental nutrients to plants by applying fertilizers in the form of composted organic material, packaged fertilizer, or a specific mineral such as iron. Soils and plants need so many more nutrients than Nitrogen, Phosphorus and Potassium (also called NPK). But research has shown that it is these three that are the primary nutrients needed to produce bigger yields. To the farmer, with all the expenses involved in farming, coupled together with low crop prices, if

he doesn't produce larger yields, he very well won't be able to make enough money to stay in business (Berry et al., 2003).

Fertilizers, either organic or inorganic, maintain soil fertility and productivity through supplying/replacing essential plant nutrients and therefore make a vital contribution to economic crop production. Cultivated soils do not usually contain sufficient amounts of plant nutrients for high and sustained crop yields. Harvesting crops removes nutrients and if they are not replaced (through use of fertilizers) soil mining results, yields will diminish, and crops will develop deficiency symptoms and in extreme cases, fail altogether. Fertilizers are necessary to support affordable and sustainable agriculture. Yara has a range of fertilizer products to provide those nutrients in short supply. Optimal fertilizer application with the correct balance of nutrients is required to ensure the economic production of both high yielding and high quality crops. Crop growth and yield are governed by climatic conditions and the availability of water and plant nutrients. At harvest, nutrients are removed from the soil by the crop and they need to be replaced. The nutrients in the soil reserves and from organic manures are not sufficient, mineral fertilizers provide the additional input required for increasing crop yields. Yield increase has followed the increase in world population and must continue to do so if hunger is to be avoided (Garcia et al., 1990).

Plants have varying nutrient needs, depending on the species, the age of the plant, and its location. It is not always necessary to fertilize your plants or lawn, but if you choose to fertilize, it is important that you do so properly. Too much fertilizer can weaken a plant, promote disease, and invite pests, in addition to wasting money and harming the environment. Appropriate use of fertilizer contributes to good agricultural practice. Mineral fertilizer applications can increase soil organic matter through higher levels of root mass and crop residues. However, incorrect agricultural practices may diminish soil fertility even where fertilizers are used: Increased yields increase nutrient removal, and those nutrients must be replaced. Poor rotations, with little or no return of crop residues or manures can result in reduced

soil organic matter content and soil fertility. Fertilizers do not cause such changes, but can mask soil deterioration for some time. (Garcia et al., 1990).

Overview of agriculture and fertilizer challenges in Rwanda

The agricultural sector has been given a high priority in the government's planning for development. The current national thrust is for the sector to move from subsistence to commercial mode of production. This strategy aims to increase household incomes and lead to a 50 per cent reduction in poverty over twenty years (MINAGRI, 2009). With its projected contribution to economic growth, modernization of agriculture is seen as one of the six pillars of Vision 2020 along with sustainable land-use management and basic infrastructure (Republic of Rwanda, 2000). Agriculture is also explicitly recognized in the EDPRS as one of the four priority sectors that will both stimulate economic expansion and make the greatest contribution to poverty reduction (Republic of Rwanda, 2007). By 2020, agriculture is envisaged to contribute 33 per cent to GDP whereas industry, including agro-processing, is expected to grow from current levels of 14 per cent to 26 per cent of GDP (Republoc of Rwanda, 2000). The use of fertilizer is likely to increase in future as the government has taken a policy decision to subsidize it and improve distribution through the use of private sector. In 2007 about 21,600 tons of mineral fertilizers were ordered and 13,260 tones were received and distributed. About 4,200 tons of mineral fertilizers were distributed under crops intensification program (MINAGRI, 2008). Further, the main crops fertilized include tea, potato, rice, wheat, and maize. The main types of fertilizers used are NPK 17-17-17 on potato, maize, fruits, and vegetables; NPK 25-5-5 on tea; NPK 20-10-10 on coffee; urea on maize, rice, and wheat; and DAP on maize, rice, and wheat. Kelly and Nyirimana (2002) estimated that less than 5% of farmers use fertilizer on less than 3 percent of cultivable land area in Rwanda. The current fertilizer application rate in Rwanda is among the lowest in Africa. Average fertilizer use intensity amount to a mere 8 kilograms of nutrients per hectare compared to the Continent and Asia average of 10 and 148 kilograms

per hectare, respectively. The results of decades of studies and assessments (IFDC, 2007; Bingen and Munyankusi, 2002; Kelly et al, 2003) into the fertilizer situation in Rwanda indicate that the low fertilizer use and application rates are a result of several demand and supply-side constraints.

3. Materials and Methods

Presentation of the study area, sample and data

The Republic of Rwanda is located in East-Central Africa between latitudes 1°04' and 2°51' South and longitudes 28°45' and 31°15' East. It is the 149th largest country on the Earth, and the fourth smallest in Africa. It is divided into five provinces (Kigali City, Southern, Western, Northern and Eastern provinces), 30 districts, and 416 administrative sectors. Administrative sectors are also subdivided into cells, which in turn are divided into villages. With the size of 26,338 square kilometers, it is bordered by the Democratic Republic of the Congo to the West, Uganda to the North, Tanzania to the East, and Burundi to the South.

Located in the Western Province of Rwanda and in the west part of the country, Nyabihu District has 12 sectors that are Bigogwe, Jenda, Jomba, Kabatwa, Karago, Kintobo, Mukamira, Mulinga, Rambura, Rugera, Rurembo, and Shyira. These areas are themselves divided into 73 cells and 473 villages. Taking into account its administrative limits, in the north there is Musanze district and the Virunga National Park, which separates it with the Democratic Republic of Congo (DRC). In the South, there is Ngororero and Rutsiro Districts, and in the East there is Gakenke and Musanze Districts. Finally, in the West there is Rubavu District.

Its geographical relief is characterized by 90% rugged mountains with a slope of more than 55% creating a high risk of erosion so that the need for the establishment of effective mechanisms for control and prevention of erosion and other harms associated with climate change is very high. The characteristic of the soil is sandy and clay, laterite and volcanic and is very fertile. Precipitation is almost uniform over every month and close to 1400 mm per year. It has a temperate climate with an average

temperature of 15^0 C favorable for the growth of the agro-pastoral products throughout the year with less risk of development of bacteria and diseases.

The economy of the Nyabihu District is heavily dependent on subsistence agriculture, where the majority of households are smallholders. Approximately 74%, or 105,672 people in 143 000 of the population of the district, derive their income from the exploitation of the soil. However, there is a scarcity of land because, according EICV3, 50% of the population has an area less than 0.3 ha. Agricultural food, industrial and ornamental products are grown extensively. For food, there are Irish potatoes, corn, beans, wheat and banana and vegetables as well. For cash crops, there are tea, coffee, pyrethrum and patchouli that contribute to economic development and household welfare improvement (Nyabihu District, 2013).

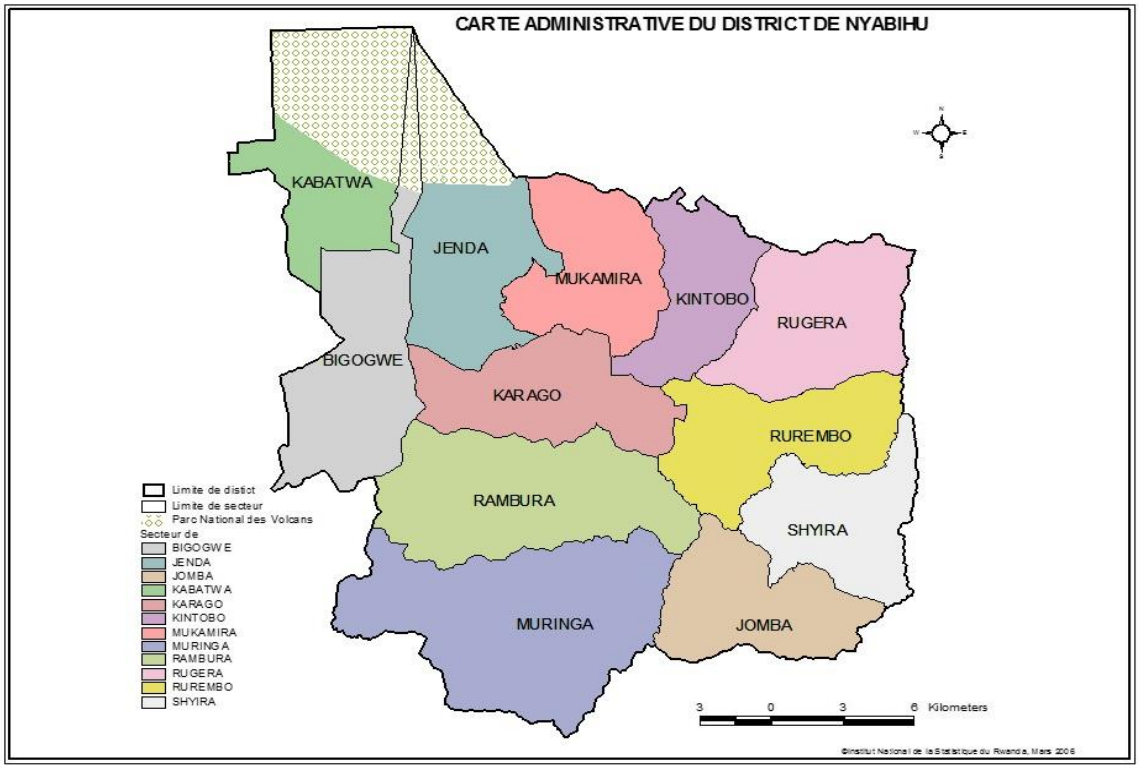

Figure 1. Map of Nyabihu District showing Kabatwa Sector

Source: Nyabihu District (2013); www.nyabihu.gov.rw accessed on November 16, 2015 at 9:47 am.

This study was conducted in Kabatwa Sector, Nyabihu District, Western province. Kabatwa is one of 12 sectors of Nyabihu District as depicted by Figure 1. The geographical coverage of this sector is estimated to 52 km^2, with a population of 18,951 inhabitants and the population density is 364 inhabitants per km^2 (NISR, 2012). With fertile volcanic soil, the major food and cash crops include potato, corn, vegetables, and pyrethrum. Even though the land is normally fertile, farmers area stiil producing at low level far from the potential yield. It is therefore very crucial to enhance land productivity to meet the needs of increasing population conditional upon proper agricultural practices.

With the intent of data collection, the sample size was determined using the Yamane's (1967) formula. The formula is set as follows:

$$n = \frac{N}{1 + N(e)^2}$$ ---------- Formula (1)

where n is the sample size, N the population of study, and e the precision level. for sample size determination.

Applying the formula (1) to N=18 951 and e=0.10, we get n=99.48, which was rounded up to get a sample of 100 respondents. Subsequently, a semi-structured questionnaire was administered and the collected information was related to season 2014 B compared to the situation before the adoption of fertilizers.

Method of data analysis

Besides descriptive statistics, inferential statistics were used to test whether there exist a statistically significant different between two mean scores of the same group at two different points in time. In this line, a paired sample t-test was used to determine if there is a difference between mean scores and whether or not that difference is statistically significant or different from zero (Jackson, 2009; Singh, 2006; Hurst, 1995). The paired sample statistic t is given by the Formula 2.

$$t = \frac{\sum d}{\sqrt{\frac{n\left(\sum d^2\right) - \left(\sum d\right)^2}{n-1}}} = \frac{\bar{d}}{\sqrt{S^2/n}}$$ --------

Formula (2)

where $\bar{d}$ is the mean difference between two samples, S^2 stands for the sample variance, n is the sample size, $n-1$ is the degree of freedom, and t is the paired samples t-test. This technique was used

just to compare mean scores of potato yields considering two points in time, that is, before and after the practice of fertilizer among potato growers in the area of study.

4. Results and discussion

Farmers' perceptions on fertilizers' effects on potato production

The table 1 summarises the farmers' perceptions on the effect of fertilizers on potato production. The research results indicate that 94% of the respondents have confirmed that fertlizers have positive effects on potato production in the study area, whereas a small number of only 4% reported that there is no effect of fertilizers on potato production. The former have reported that fertilizers have enhanced the increase in potato production, whereas the latter have said that the use of fertlizers has not induced the increase in potato production.

Table 1: Farmers' perceptions on fertilizers' effects on potato production

Farmers' perception on fertilizers' effects	Frequency	Percent	Cumulative percent
Increase in potato production	96	96.0	96.0
No increase in potato production	4	4.0	100.0
Total	100	100.0	-

Fertilizers are not used for fun but because people (farmers) hope that fertilizers increase the productivity of the soil. There is always a hope for higher output when fertilizers are applied than when the farmer cultivates the land naturally. On the same piece and size of land, the farmers provided information on their production before and after the application of fertilizers.

Comparison between production before and production after the adoption of fertilizers

Following the information contained in the table 5, the average potato production or output after application of the fertilizers (2,055 kgs) was much higher than the average potato production before the application of fertilizers (900 kgs).

In the attempt of comparison of the production levels before and after the adoption of fertilizers to determine whether the average potato productions before and after the adoption of fertilizers are statistically different, a paired-samples t-test was conducted. The results from the paired-samples t-test in the table 2 show that the difference between the average potato production after and the average potato production before the adoption of fertilizers in the study area (1,155 kgs) is statistically different from zero following that the corresponding p-value (as observed in last column of the table 2 labelled Sig. 2-tailed) is 0, that is smaller than 0.05. This also confirms the information contained in the table 5 indicating that the average production after the adoption of fertilizers (2,055 kgs) is greater than the average production before (900 kgs). The t-test shows that the former average is statistically different frm the latter.

Table 2: Paired-samples t-test of potato production before and after the application of fertilizers

Parameter	Mean	Std. Dev.	95% Confidence Interval of the Difference		T-test	Df	Sig. (2-tailed)
			Lower	Upper			
Potato production after fertilizer use – Potato production before fertilizer use	1155	35.32	1084.9	1225.1	32.7	99	0.0000

The major problems related to fertilizer utilisation

While analyzing the major problems linked to fertilizer use in the study area, the respondents reported that the cost of is high (34%), the long distance between farmers and suppliers (30%), late delivery of fertilizers to the farmers by the suppliers (10%), insufficient knowledge of the correct use of fertilizers (10%), and

land fragmentation or exploitation of small plots (10%). The constraints of the the best use of fertilizers are well described in the table 3.

Table 3: Constraints of fertilizers utilization among potato growers

Constraints identified	Frequency	Percent	Cumulative percent
High cost of fertilizers	34	34.0	34.0
Long distance to fertilizer market	30	30.0	64.0
Late delivery by suppliers	10	10.0	74.0
Insufficient knowledge on appropriate use of fertilizers	10	10.0	84.0
Land fragmentation (small plots)	16	16.0	100.0
Total	100	100.0	-

Discussion of the findings

The results of this study revealed that potato growers have positive perceptions of the effects of fertilizer practice on potato production. This may be due to the fact that they have observed an increase in potato yields. This finding sustain Marenya et al. (2008) who specified that the farmer's perception on fertilizer practice is primarily driven by observed crop yields. Another majour finding is that the practice of fertilizer contributed to significant increase in potato production in the study area. This supports Lal (2006) who stated that productivity gains come from the appropriate use of fertilizers, and Chen (2006) who underlined the role of chemical fertilizers for the plant growth. This is also in line with Cantore's (2011) finding that improved inputs are among the primary determinants of productivity. Thes results also support Maniriho and Bizoza (2018) whose study revealed that the fertilizers are among the primary drivers to scale up the crop production. The last finding is that the high cost is the challenge that hinders the potato growers to practice appropriately the fertilizers on their lands. The same challenge was also

highlighted by Berry et al. (2003) who reported that the farmer should do all the best to produce larger yields to cope with the high expenses involved in farming and manage low crop prices.

5. Conclusion and Recommendations

This research assessed the effects of fertilizer adoption on land productivity in Kabatwa Sector, Nyabihu District, Western Rwanda. Data were collected through a field survey conducted to gather information for season 2014B. A well structured questionnaire was administered among 100 farmers selected randomly in the study area. Descriptive statistics and paired-samples t-test were used to analyse data. The respondents comprised 55% of males and 45% of females. The results show that 73% of the respondents have highly appreciated the contribution of fertilizers to land productivity whereas 27% have depreciated the effect of fertilizers to land productivity. A number of factors have been identified as the constraints to the correct use of fertilizers. These include the high cost of fertilizers, long distance between farmers and suppliers, exploitation on small plots, late delivery of fertilizers, and insufficient knowledge of the correct use of fertilizers as it was reported by 34%, 30%, 16%, 10%, and 10% of the respondents respectively. Further, the comparison between the average crop production after and the average crop production after the adoption of fertilizers indicates a difference of 1,055 kgs which is statistically different from zero given the that $p \leq 0.05$ following the results of paired-samples t-test. All the results indicate that the adoption of fertilizers has positively contributed to land productivity in the study area.

Based on the research findings here above presented, it was recommended that regular training of farmers on the best use of fertilizers. Farmers' cooperatives should also be enhanced to enable farmers to cope with late delivery and unnecessary costs involved by the middleman. Finally, the government should keep on investing in the subsidization of improved agricultural inputs.

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