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Economic Analysis of Growth Performance of Various Grains Crops During Agricultural Reform in Rwanda

Theodore Murindahabi* Qiang Li E.M.B.P. Ekanayake
School of Economics and Management, Beijing Forestry University, No. 35, Qinghua East Road, Haidian District, Beijing, 100083, P.R. China

Abstract
The grain crops have been the main staple food crops in Rwanda, by complementing or substituting root-tubers and plantains in everyday diet. As agriculture is considered as backbone of country's economy, its transformation was thought to be engine of economic development. Using the time series data of 15 years, the present paper intends to analyse growth performance in area, production and productivity of grains crops during agricultural reforms in Rwanda. The results of study showed that a positive and significant growth rates were recorded in the case of cultivated area and production of wheat, rice, maize, millet, beans, peas and groundnut. Being among prioritized crops during reforms, wheat, rice and maize experienced the highest positive growth rates in cultivated area, production and productivity with high significant level ($p<0.001$) for all growth rates, except a non-significance case of productivity growth rate in maize. The soybeans reported a positive non-significant growth rates in area, production and productivity while sorghum undergone a negative significant growth rate ($p<0.001$) in area, a negative non-significance in production growth rate, but a positive significant growth ($p<0.01$) in productivity. The area under cultivation, production and productivity of maize, wheat, rice and soybeans were highly unstable regarding to other grains crops. The cultivated area was generally the major contributor for change of grains crop production. The influence of both area and productivity on production was highly remarkable for wheat, maize and sorghum. This study concludes that generally, the agricultural reform has had tremendous positive impact on growth rates of grain crops in Rwanda but it suggests policy implications to increase productivity of some grain crops.
Keywords: Growth rates, Instability, Component Analysis, Grain Crops, Agricultural Reform, Rwanda

1. Introduction

The grains crops which include cereals (wheat *Triticum aestivum,* Maize *Zea mays,* Sorghum *Sorghum spp,* Rice *Oryza sativa* and Finger Millet *Eleusine coracana),* oilseeds (soybean *Glycine max* and groundnut *Arachis hypogaea*,) and pulses (common bean *Phaseolus vulgaris* and Pea *pisum sativum*) have been the main staple food crops in Rwanda. They have served either as complementary food or substitute of root-tubers (cassava, sweet potato, irish potatoes, yam and taro) and plantains in everyday diet. Moreover, they are the only seasonal crops whose storage would be easy from the first harvest period to the next harvest. According to the recent year's data, some grain crops have highly contributed to the country's economy through increasing agricultural exportation (NISR, 2016). Since agriculture is considered as backbone of country's economy which contributes 32% of GDP and 0.8 percent points to the overall GDP growth rate (NISR, 2017) provides 72% of country export revenues and about 90% of national indispensable (IPAR, 2015), its transformation was among the main agenda of Rwanda Vision 2020 - key intending to transform Rwanda into a knowledge-based-middle income country by alleviating poverty and maintaining welfare of population (MINECOFIN, 2000).

In developing countries like Rwanda, agricultural growth has been a leading driver of poverty reduction and economic development. The study of Virmani (2007) reported that the agricultural growth in India reduced the poverty and contributed to the GDP growth. This study found that for every increase of 1% in agricultural growth decreases the rate of poverty by 0.45%. Moreover, Thirtle et *al. (*2001) found that no other sector has more splendid impact on poverty than agriculture. Their study stated a significant relationship between agricultural growth and poverty reduction: every growth of 1% in agricultural productivity makes a decline between 0.6% and 1.2% of the percentage of people who use a less than a dollar per day to survive.

In order to sustain economic growth, it is crucial to quantify the impact of many different factors toward agricultural output. The area under cultivation and productivity are among factors underwriting to the agricultural growth (Singh, 1981). They are crucial for agricultural development plans and for making priorities in investment (Ranede, 1980). Knowing the previous trend of agricultural production and the estimation of its growth rates can deliver a base for future estimates of agricultural output. Therefore, the present study makes an attempt to analyze the agricultural growth, fluctuations of agricultural components and the role of these several components to total output growth of various grains crops in Rwanda during 15 years agricultural reform (from 2000 to 2014).

2. Review on grains crops status in pre-and post agricultural reform

The pre-agricultural reform refers to the period before policy reforms which was initiated in 2000, while the post agricultural reform represents the period after 2000 until now. During 1960-1980, the food production was

increasing faster than population in Rwanda, and it was among rare cases recorded in few African countries at that time. However, in mid 1985s, the agriculture growth failed to follow the same pace with population growth because it was drained by scarcity of arable land (Kangasniemi, 1998). The analysis of agricultural data collected during 1982-1983 year showed that the average land area cultivated by each household was small with average of 1.24 ha (Muller, 1997).

From 80's, Rwanda was facing problems of insufficient agricultural production and food insecurity. The problem was exacerbated by civil war of 1990-1994 which led the country to chaos with high loss of human capital, destruction of infrastructure and institutions. After war, the country has started to rebuild but was facing serious socio-economic problems: about 87% of the population was living in rural area with small farms less than 1 ha; low agricultural productivity due to continued land degradation by erosion and low use of agricultural inputs (MINAGRI, 2004).

The Agricultural relied almost on rain and takes place mainly on hillsides with crops such climbing bean, wheat, maize and irish potatoes in highlands and with bush bean, sorghum, cassava, sweet potatoes and banana, in the low and midlands. Referring to the data from FAO (2014), the productivity of grains crops started to shrink; for instance, the high productivity for all cereals was recorded in 1987 with 1282.9 kg per hectare, continued to decline to 973 kg per hectare in 1998. For beans, the high productivity of 923.3kg per hectare was experienced in 1985 but it decreased to 560.6 kg per hectare in 1997.

Since 2000, Rwanda has implemented the agricultural reform which has been embedded in a framework of national and international development goals. It aligns with Millennium Development Goals (Global development aspirations by 2015), Common Markets for Eastern and Southern Africa, the East African Community, Rwanda Vision 2020 (Key intending to transform Rwanda into middle income economy) and Economic Development and Poverty Reduction Strategy (Alinda and Abbott, 2012). The policy reforms were structured in complementary and successive way where each reform or strategy was implemented to fulfil the goals of the previous one (See Appendix 1). As grains are main staples crops complementing the root-tubers in Rwanda, any reform on agriculture has had impact on their production.

The agricultural reform has done in different processes in which the agricultural policies, strategies, programmes and initiatives were implemented. The reform encompassed many aspect of agricultural value chain includes activities needed to produce, harvest and sell products (agriculture mechanization, land use management, input supply, extension, post-harvest handling, market information and planning). The grain crops were among targeted food crops during reform (i.e. development and implementation of National Rice Policy). The main purpose of this reform was to increase productivity and ensuring national food security through agriculture modernization and professionalism (See the Appendix 2).

Based on various agro-ecological zones described by Rwanda Agricultural Board (RAB), the grain crops accounted a great number among the eight staple crops (maize, rice, wheat, beans, soybeans, peas, Irish potato and cassava) which were given priority during agricultural reform, especially under Crop Intensification Programme and Land Used Consolidation policy implemented in 2007 and 2008 respectively. The reform has permitted the farmers to get the various agricultural services such as improved seeds and fertilizers delivery, agricultural extension services, irrigation and mechanization, facilities in post-harvest handling and storage and concentrated markets for inputs and output (Mbonigaba Muhinda & Dusengemungu, 2013).

During the reform, the consolidated land area (the reallocated land) has increased rapidly and resulted to the potential production and yield of grain crops. For instance, the consolidation land area under maize has increased from 17, 808 hectares(ha) during agricultural season A (September to December) of 2008 to 83,470.70 ha in season B (February to May) of 2011. From the 61.1% of the total area under maize cultivation, the consolidated land area under maize produced 83.3% of total national production with the yield exceeding 4000kg/ha (Kathiresan, 2012). Note that the introduction and adoption of hybrid maize has been the single most important impact on maize production through seed and fertilizer subsidies provided by government (USAID, 2016).

The investment and capacity trends in agricultural sector during agricultural reform have also focused on developing agricultural research. The maize, rice and wheat were among the most heavily researched commodities with the shares of 9, 6 and 5.7 percent respectively of full-time equivalent (FTE) crop and livestock researchers across agencies (Flaherty and Munyengabe, 2011). The period from 2001 to 2011 was remarked by tremendous research achievement of some grain crops which led to releasing high yielding and diseases resisting varieties (i.e *Gasilida*, a bean variety with 4000-4500kg/ha, resistant to common bean mosaic virus[1]). The new eleven varieties of maize were developed with mid-altitude varieties (Z6M07, *Pool 32*, ISARM081, ISARM101, ISARM102, ISARM103, ISARM104, RHM101, RHM102, RHM103,) and one variety for highland (ISARH071). In addition, seven varieties of rice were released with four varieties for mid-altitudes (WAB543-45-2, *Gakire*, *Instindagirabigega* and *Instinzi*) and three varieties for low-altitude (IR64, WAT54 and IR65192-4B-17-3). Fifteen

[1] N2Africa. 2014. Better beans through good agricultural practices for farmers in Rwanda. Available at www.N2Africa.org and www.cabi.org/ashc.

beans varieties were developed with four climbing beans varieties for the highlands (RMV2070, *Gasilida*, RWV1129 and CAB2), three climbing beans varieties for mid-altitudes (MAC44, MAC9, and MAC49) and nine bush beans varieties (RWR2245, RWR1180, RWR2154, RWR3042, RWR2076, *Pyramide*, RWR2340, SER16 and SER30) suitable for all country's ecological zones. They developed simultaneously advanced approaches in controlling the grain crops' diseases and pest, as well as improving their productivity through Integrated Soil Fertility Management approach (Gahakwa et *al*., 2014).

The research effort for grain crops has continued to produce new varieties with high yield, quality and resistant to the diseases. The research focused also to the evaluation of imported varieties as well as to the study of grain crops' diseases occurrence. In 2013, Rwanda Agriculture Board (RAB) released four varieties of soybeans (*Sc.Squire, Sc.Saga, SB 24 and Sc.Sequel*) which provide high yield, tolerant to diseases such as rust, FrogEye Leaf Spot and Red Leaf Blotch. The new varieties were considered to make improvement production comparing to the usual varieties (*Peka 6, Bossier, Ogden, Duiker, 449/16, Soprosoy, Yezumutima, Buki, and 1740-2E*[1]*)* of soybeans (MINAGRI, 2013). The soybean has been promoted because of its adaptability to the Rwanda's climate, nutritional value, and the way it responds to the mineral and organic fertilizer inputs(Mugabo et al.,2014).In the same year, the research on sorghum started and it has resulted to the development of four types of varieties: F1 and F2 early maturing , low tannin , and high yielding white grain sorghum varieties**;** F3 early maturing and high yielding red sorghum varieties ; F3 early maturing, high yielding white grain sorghum lines for highlands and F4 early maturing, high yielding sorghum lines for multipurpose use. In addition, ten varieties of wheat (*Stallion, Smart , Serena ,Nduna, Sky, Shungu ,Select, Shield, Shine, Sekuru,*)obtained from Seed Co Zimbabwe were evaluated , and one variety(*Shine*) was found to be the best line in terms of agronomic performance. For the grain crops's diseases case, the study was done to understand the population structure of the rice blast disease pathogen (Magnaportheoryzae) after being observed to the three varieties of rice namely *Facagro, Yun-yin and Intsindagirabigega* (RAB,2015).

Broadly speaking, the agricultural reform has resulted to the improvement of various grain crops production. The data of harvested dry grain cereals reported in 2014 by FAO (2014), showed that the land under cereal production was 438,985 hectares (ha) with the production of 869,480 metric tons, counting the yield of 1981kg per hectare. The rice showed high yield (3,059.4kg/ha), followed by maize (2,501kg/ha), wheat (2,008kg/ha) and sorghum (1,024.4kg/ha). Millet had the lowest yield (418kg/ha) among other cereals. Comparing the country's cereals production with neighbouring countries, Rwanda was the second cereals producer after Uganda which produced 3,558,000 tons on cultivated area of 1,762,000 ha with the yield of 2,019.3 kg per hectare .However, the pulses and oilseeds showed low level in cultivated area, production and yield comparing to cereals. The beans (dry) were cultivated on 465,865 ha, produced 415,259 metric tons with productivity of 891.4 kg/ha. The peas follow beans with the yield of 475kg/ha while soybeans have the lowest productivity of 547kg/ha .The productivity of groundnuts was the lowest (370kg/ha) among all grain crops (FAO, 2014).

Furthermore, since agricultural reform, the cereals have become important staple crops playing a significant role in agricultural production and cross-border trading of agricultural commodities. For instance, maize is the third-largest crop regarding the cultivated area, fastest growing in area with a tripling cultivated area since 2009, and showing a fastest production growth as well as rice (USAID, 2016). Its production has increased extremely from 175,000 metric tons in 2008, to an estimated 575,000 metric tons in 2012. The trade data for maize indicated that between 2009 and 2012 year, Rwanda was a net importer of maize grain and a net exporter of maize meal (USAID, 2013). Unfortunately, during the year 2013-2014, the effects of climate namely unreliable rainfall patterns and new disease(*Maize Lethal Necrosis*) affected the maize production(RAB,2015).Since 2012, the cereals have showed an increase in the exported quantity: the total cereals grain and flour exported in 2012-2013 were 38789010 kg; 37201352 kg in 2013-2014; 51428305 kg in 2014-2015, and 54724337kg in 2015-2016 generating the revenues of USD 31090712;USD 28652841;USD 32310827 and USD 27680463 respectively (NISR, 2016).

Considering the pulses production in Rwanda, common bean (*Phaseolus vulgaris)* has been the most important staple crop daily consumed by great number of population within country. With 56% fiber and 25% protein content, common bean become an important complement to tuber and starchy cereal-based diets (Gietz et *al*., 2015). Two types of common beans: bush and climbing are grown in both season A (September to December) and season B (February to May). The value of common bean is shaped in terms of food security, nutritional value (bio fortified common beans varieties with high-iron content), national consumption, geographical coverage and a great percentage (92%) of farmers producing it (USAID, 2016). Despite the area of beans sown has remained relatively stable, the average productivity has increased of 40 percent due to the yield improvement made in climbing beans. The trade data showed that between 2009 and 2012, Rwanda has been a net exporter of beans even the quantity traded was relatively low considering the significance of beans as the primary national staple crop. In 2011, the quantity of beans exported was 5.9 percent of annual production comparing to the imports which

[1]Actual soybean varieties cultivated in Rwanda. Source: Soybean programme, ISAR.,cited in Mujawamariya (2012).

were less than 1.6 percent (USAID, 2013).

3. Methodology

The objective of this study was to assess the growth rate in area, production and productivity, simultaneously estimating instability in growth of various grain crops in Rwanda during agricultural reform. The study was based on secondary data of major crops for the 15 years period since implementation of agricultural reform in 2000. The data from Food Agriculture Organisation (FAO) on cultivated area (ha), production (t) and yield (t/ha) of rice, wheat, maize, sorghum, millet, beans, soybeans, peas and groundnuts from 2000 to 2014 were used. The exponential model of the following form $Y_t = ab^t e^u$ was fitted from the regression methods to examine the trends in area, production and productivity of mentioned food crops.

$$Y_t = ab^t e^u \qquad (1)$$

Where:

$\mathbf{Y_t}$ = area/ production/productivity of the crop in the year t (dependent variable for which growth rate is to be estimated).

a= Intercept indicating Y in the base period when t=0

t= Time variable (time period in years)

b= Regression coefficient (trend)

e=Neperian base

u= Error term (disturbance term)

The above equation (1) was linearly transformed by taking logarithms of its both sides: $\mathbf{Ln\ Y_t = lna + t\ lnb + u:}$

The exponential function provides a geometric rate of growth and represents a uniform rate of change from year to year. The value of **b** indicates the directional change of dependent variable during a specific period. The value of coefficients **a** and **b** was gotten by using the technique of Ordinary Least Squares (OLS) estimation. The study considered that the change in agricultural production in year was depended upon the production of the preceding year. Therefore, estimating growth of agricultural output over time by using linear function may turn out to be less efficient than log linear. According to Gujalati (2010), the Compound Growth Rate (CGR) which represents a uniform rate of change from year to year is calculated by taking Antilog of estimated value of **b** for the time period (t), subtracting 1 from it and converts the results into percentages.

Compound Growth Rate (CGR) = $\left(Anti\log b - 1\right)\times 100$ (2)

$$= (e^b - 1)\times 100$$

The positive value of **b** (b>0) indicated the growth overtime while the negative value of **b** (b<0) showed a deceleration in the growth. A value of **b** close to zero indicates absence of any trend (Chinnapa, 2003). Growth rates were tested for their significance using the students "t" test.

Instability Index (CD)

It is known that agricultural sector is generally subjected on four main factors namely, social factors, economic factors, political factors and natural factors. The natural factors include climate, topography (land relief) and soil. While it would be painless to manage these three factors, yet somehow, it is absolutely complicated and may seem impossible to master and ensure the management of natural factors. The bastardized variation of these natural factors results to the fluctuations of agricultural components (land area, production or productivity) and it leads to the growth with instability. However, the growth rates fail to clarify the fluctuations in time series. Therefore, the index (CD) given by Cuddy and Della Valle (1978), used by some researchers, for instance Larson et al. (2004), Sahu and Mishra (2011), Ali and Jabbar (2015) will be used as a measure of instability (variability) in area, production and yield. According to Hasan et *al. (*2008), this index is a better way to explain properly the inherent trend component in time series than using a general way of a Coefficient of Variation (CV). By using CV, we get overestimated value of instability in the time series whose term trends are long. Fortunately, the Cuddy and Della Vallet (1978) Index (CD) adjusts the instability. This index is stated with the following formula:

$$CD = CV * \sqrt{1 - R^2} \qquad \text{with} \quad CV = \frac{\sigma}{X} * 100 \qquad (3)$$

Where: CD = Coefficient of Variation (CV) around trend (Instability Index)

CV = Coefficient of Variation

σ = Standard Deviation

$\bar{X}$ = mean

The standard deviation is a positive square root of the variance and it was calculated as follow:

$$\sigma = \sqrt{\frac{\Sigma Y^{2} - \left(\frac{\Sigma Y}{n}\right)^{2}}{n}}$$

Where: $\sigma =$ Standard deviation

Y=Area, production, productivity

n =number of observation

Component Analysis Model

Different researchers used the Component Analysis Model to determine growth performance of crops (Bhatnagar and Nandal, 1994; Mundinamani *et al*., 1995; Kakali and Basu, 2006; Siju and Kombairaju, 2001) to measure the contribution of area and productivity toward change in production of major crops. The model states that the variation in production is the sum of contribution of area and yield and their interaction effects (area x yield). The model helps to calculate their percentage share.

$$\Delta P = \Delta A Y_{to} + \Delta Y A_{to} + \Delta A \Delta Y \quad (4)$$

$$\%\bar{A} = \frac{\left(A_t - A_{to}\right) Y_{to}}{\left(P_t - P_{to}\right)} * 100$$

$$\%\bar{Y} = \frac{\left(Y_t - Y_{to}\right) A_{to}}{\left(P_t - P_{to}\right)} * 100$$

$$\%\bar{A}.\bar{Y} = \frac{\left(A_t - A_{to}\right)\left(Y_t - Y_{to}\right)}{\left(P_t - P_{to}\right)} * 100$$

Where: $\%\bar{A}$ = Percentage share of area

$\%\bar{Y}$ = Percentage share of productivity (yield)

$\%\bar{A}.\bar{Y}$ =Percentage share of interaction (interaction effect)

$A_n - A_0$ = Change in area

$Y_n - Y_0$ =Change in productivity (yield)

$P_n - P_0$ = Change in production

A_0 , Y_0 , P_0 =Area, Productivity (yield) and production in base period respectively

A_n , Y_n , P_n =Area, Productivity (yield) and production in current period respectively

4. Results and Discussion

Table 1 encapsulates the growth rates of cereals, pulses and oilseeds generally indicated a positive growth in cultivated area, production and productivity of studied crops (except sorghum for growth in area and production, millet and groundnuts for productivity).

Table 1: Compound growth rates of area, production and productivity of various grains crops

Crop type	Growth rates (%)		
	Area	Production	Productivity
Cereals:			
Maize	8.42 ***	20.63 ***	7.66
	(0.0074292)	(0.0183279)	(0.0347403)
Rice	10.02 ***	14.00 ***	3.61 **
	(0.0153596)	(0.0204068)	(0.0116143)
Sorghum	-3.85 ***	-1.46	2.49**
	(0.007051)	(0.0068193)	(0.0065002)
Wheat	10.80***	22.29 ***	9.86***
	(0.0177668)	(0.0208244)	(0.0098267)
Millet	5.09 ***	0.88 ***	-4.01***
	(0.0076354)	(0.000942)	(0.0070152)
Pulses:			
Beans (dry)	2.09 *	5.44 ***	3.29 ***
	(0.0069645)	(0.0075467)	(0.0062866)
Peas (dry)	2.11 **	5.18 **	3.00 **
	(0.0061453)	(0.0126171)	(0.0078374)
Oilseeds:			
Soybeans	2.73	4.72	1.94
	(0.0163832)	(0.0265689)	(0.0115592)
Groundnuts	4.28***	3.25 **	-0.99
	(0.0050405)	(0.0097992)	(0.008995)

Note: Figures in parenthesises represent the standard error (Std. Err.).
*=significant at 5% ($p<0.05$);** = significant at 1% ($p<0.01$);***=significant at 0.1 %($p<0.001$)
Source: Authors' estimation

It shows that the area under wheat and rice recorded the highest growth rates of 10.80 and 10.02 percent per year respectively with high significant level of 0.1 percent for all of them. Other cereals (except sorghum) registered the annual growth rates in area higher than all pulses'. This is to mention the maize and millet which had 8.42 and 5.09 percent respectively with a high level of significance (0.1%) for both, comparing with groundnuts (4.28%), dry peas (2.11%), common beans (2.09%) which showed low growth rates significant at 5, 1 and 0.1 percent respectively. Indeed, despite it was among prioritized food crops, the growth rate in area of beans was below the growth rate in area of many non-prioritized grains crops such as peas, groundnuts and millet.

The highest growth rates in the area under wheat, rice and maize cultivation, the slight growth rate of millet and a decrease in growth of area under sorghum cultivation can be explained referring to the previous studies. Mbonigaba-Muhinda and Dusengemungu (2013) mentioned that during Farm Land Use Consolidation Policy in Rwanda, which was triggered by Crop Intensification Program (CIP), wheat, rice and maize were the only chosen cereals among eight prioritized food crops (Irish potato, cassava, beans, maize, wheat, rice, banana and soybean). The policy's target was to increase the cultivated area of prioritized crops through consolidated arable land. The study of Kathiresan (2012) showed that in 2011, the consolidated arable land for wheat was 77.6% of targeted figures while consolidated land under rice and maize farming transcended by 7.5% and 6.3% respectively of the target assigned under CIP. Her study argued also that the increased arable land for prioritized food crops induced the gradual decline of the share of land area under cultivation of other food crops. Between 2004 and 2011, there was reduction from 52.6% to 42.4% of total land area under cultivation of other non-prioritized food crops.

In addition, the growth rate in area of each crop can be attributed to the Organic Land Law introduced by the government of Rwanda in 2005. The Law has declared that the state was mandated to manage the country land for the public interest to underpin the economic development and welfare of society (Kathiresan, 2012). The Land registration was carried out countrywide by the National Land Bureau in the same year, using GPS equipment and centralizing data in software to facilitate agricultural land management (USAID, 2016).

The lower growth rate in area of beans compared with other non-prioritized grains 'growth rate can be explained by the small size of arable land per household, high rate of bean cultivation within whole country, and Land Use Consolidation Policy. According to USAID (2016), the average arable land per every household farmer is below 0.7 ha. Moreover, "being considered as meat of poor", beans are ranked number two (after banana) as most well-liked crop grown in Rwanda, and they are cultivated by about 86 percent of farmers (CIAT, 2004). Therefore, they occupied a high share of arable land area counting 40 percent (CIAT, 2008). In other side, during implementation of Land Use Policy, crop rotation system was based on three criteria: crop convenience in a particular agro-ecological zone, its support to the general food security, and comparative advantage (MINAGRI, 2010 cited in Mbonigaba- Muhinda and Dusengemungu, 2013). With this point, it is evident that the area under

beans cultivation was slightly increased considering other crops.

Wheat, maize and rice showed a splendid positive annual growth in production among cereals while all oilseeds and pulses recorded a reasonable growth in production per annum. The wheat registered the highest growth of 22.29 percent in production, followed by maize (20.63%), rice (14.00%) and then millet with low growth of 0.8 percent. All these cereals were highly statistically significant at 0.1 percent. Notwithstanding increased growth of these cereals, the growth in production of sorghum also continued to be negatively attenuated with a non-significant decrease of -1.46 percent. The dry beans were the first food crops among pulses to record the highest fine annual growth in production of 5.44 percent that was statistically significant at 0.1 percent. They were closely shadowed by peas (5.18 %) with significant level of 1 percent, soybeans (4.72%) with non-statistical significance, and then by groundnuts (3.25%) which was significant at 1 percent.

Apart from supplied inputs and agricultural extensions provided to the farmers, the growth in these grain crops was driven also by implementing strategy to reduce crop post-harvest losses and facilitating small holders and low-income farmers to get access on reliable markets and sell their harvests at competitive market prices. These were done through market oriented initiatives such as Purchase for Progress initiative (P4P) which was launched by Ministry of Agriculture and supported by World Food Program, and also National Post-Harvest Staple Crop Strategy. In the places where the arable land was consolidated for different crops, the driers and food storage facilities were built. The execution and accomplishment of these initiatives were assisted by the presence of Agricultural cooperatives, creation of Agricultural Export Development Board, the eSOKO (domestic markets reforms), Rwanda Commodities Exchange Market and Rwanda Grains and Cereal Corporation (RGCC). The *eSOKO* was created to prevent farmers from middlemen exploitation in order to sell their products at convenient market prices. Rwanda Commodities Exchange Market was launched to connect with the exchanges of other member states of East African Community while Rwanda Grain and Cereal Corporation (RGCC) was launched to deal with the problems of grain and cereals trading in the country (Nkunzimana et *al*.,2015).

Table 1 shows also that since the implementation of agricultural reforms, the productivity growth rate of studied grains crops has followed a positive trend apart from millet and groundnut which experienced negative trend. The wheat counted the highest positive annual productivity growth rate of 9.86 percent with a high significant level of probability ($p<0.001$), chased by maize (7.66%) with non-significant level of probability. The rice and sorghum recorded well-nigh a growth rate of 3.61 and 2.49 percent respectively showing statistically the same level of significance ($p<0.01$).

The millet was sole cereal to undergone the negative trend (-4.01%) in productivity which was devilishly statistically significant ($p<0.001$). Excluding groundnut, the three oilseeds and pulses proved the positive growth rates in productivity although one of them (soybean) was statistically non-significant at conventional level of probability. The common bean and peas evidenced approximate growth rates of 3.29 and 3.00 percent, significant at 0.1 percent and 1 percent respectively. However, the trend in groundnut productivity was slightly negative (-0.99%), though it stands at non-significance level.

The growth productivity of studied grain crops can be attributed to the implementation of National Seed Policy, the Agricultural Mechanization Strategy, the improved seed (high yield capacity and resistant to diseases) fertilizer and pesticides subsidies provided by government (USAID, 2016). The seed law focuses mainly on seed production, control, marketing and commercialization of quality seed in Rwanda (Nkulikiyimana, 2010). The efforts of government to invest in food crops production has led to the increasing of arable land through reclamation of uncultivated inland marshlands, buildings some small dams in valleys for irrigation, organizing and maintaining cooperatives, and privatization of grain mills (Kathiresan,2010). The efforts in investment has contributed to the development of agricultural research where high yielding and disease resistant new varieties of grain crops were released (MINAGRI, 2013; Gahakwa et *al*., 2014; RAB,2015).

The results of instability in area, production and productivity of grains crops were presented in Table 2. The evidence from this table shows that all grains crops experienced the instability index (CD) in area, production and productivity. For cereals, the instability in area was high in wheat (24.81%), followed by rice (20.42%), millet (14.05%), maize (12.87%) and sorghum (10.57%). The soybean (28.48%) was the first to record the high variability in area, exceeding the double of each crop among all pulses and oilseeds.

The high instability in crop production was seen in three cereals namely maize (28.70%), wheat (25.78%), rice (22.87%) while lower instability was found in millet (1.54%). The soybean (45.98%) continued to keep the high variability even in production while bean (7.84%) and peas (5.25%) had low instability of unities.

Table 2: Instability in area, production and productivity of various grain crops

Crop type	Instability (%)					
	Area		Production		Productivity	
	CV	CD	CV	CD	CV	CD
Cereals:						
Maize	40.91	12.87	86.37	28.70	53.11	45.75
Rice	40.70	20.42	46.71	22.87	23.63	18.03
Sorghum	19.45	10.57	13.55	11.63	15.70	10.83
Wheat	46.85	24.81	73.74	25.78	45.92	16.18
Millet	29.00	14.05	04.26	01.54	18.81	09.90
Pulse:						
Beans (dry)	15.75	12.16	26.68	07.84	17.17	09.86
Peas (dry)	14.16	10.29	32.92	05.25	19.26	13.31
Oilseeds:						
Soybeans	31.30	28.48	51.03	45.98	0.64	18.74
Groundnuts	20.69	08.23	21.24	15.75	03.39	03.24

Source: Authors' estimation

Regarding to the productivity, all crops recorded the instability. The highest magnitude of instability was highly noticed in maize (45.75%). The other two cereals namely rice (18.03%) and wheat (16.18%) had moderate instability while sorghum (10.83%) and millet demonstrated low variation in productivity. Moreover, for pulses and oilseeds, the instability in productivity was moderate for soybean (18.74%) and peas (13.31), low for dry beans (9.86%) and groundnuts (3.24%).

A part from climate variations, these instabilities can be attributed to the agricultural reform: the quantity and quality of improved seeds, fertilizers and pesticides use, agricultural mechanization practices and Land Use Consolidation through Crop Intensification program can be seen as main driver of grain crops instability.

Table 3: Contribution of area and productivity towards change in production of grains crops

Crops	Contribution towards production (%)		
	Area	Productivity	Interaction Effect
Cereals:			
Maize	19.42532575	30.77541127	49.79781072
Rice	87.24725671	2.288463214	10.46277227
Sorghum	226.5714978	-160.6699477	34.09768722
Wheat	24.90841183	22.06065556	53.03519545
Millet	1009.10714	-426.7857143	-482.3532143
Pulses:			
Beans (dry)	42.8879497	40.85224774	16.26463944
Peas (dry)	73.4905452	21.45830766	5.071781516
Oilseeds:			
Soybeans	96.92817291	2.450160844	0.678826338
Groundnuts	233.0363607	65.11320737	-67.95220705

Source: Authors' estimation

The evidence from Table 3 showed that the cultivated area was generally the main contributor for change of crop production in cereals, pulses and oilseeds. The area was sole major contributor, exceeding two hundred percent in the case of sorghum (226.57%), and reaching over one thousand percent (1009.11%) for millet. Also, the rice (87.25%) saw its change in production with great percentage share of area. Besides cereals, the area was the major contributor in groundnuts (233.04%), followwed by soybean (96.93%) and peas (73.49%).

In all studied staple crops, the contribution of productivity was quite low and some of them showed the critical negative level. Maize was the only crop to record the percentage share of productivity (30.78%), greater than the contribution of area. The contribution of productivity in wheat (22.06%), dry common beans (40.85%) and peas (21.46%) were lower than area's but in the same range. Both area and productivity collectively affected the production mainly in cereals like wheat, maize, and sorghum registering 53.03 percent, 49.80 percent, and 34.10 percent respectively. However, their influence is low in pulses with bean being the sole crop to experience over ten percent (16.26%).

5. Conclusion and Policy Implications

Grain crops have played an important role for food consumption and security and have recently highly contributed to the economic growth in Rwanda through exportation. As agriculture is a paramount source of the country

economics, its reform was among the main agenda of Rwanda Vision 2020 - key aiming to transform Rwanda into a knowledge-based-middle income country. Normally, the trend of agricultural production in the past and the estimation of its growth rates can provide a basis for future projections of agricultural output. Therefore, the present study was conducted to assess growth rate, variability of agricultural components and the contribution of these various components to overall output growth of various grains crops in Rwanda from 2000 to 2014, a period of 15 years of agricultural reform. The study found that among all grain crops, three cereals namely wheat, rice and maize recorded the highest positive growth rates in cultivated area, production and productivity with high significant level ($p<0.001$) for all growth rates, excluding the case of non-significant in productivity growth of maize. However, two cereals such sorghum and millet experienced a significant positive low growth rate and decreased in different agricultural components. In general, the pulses and oilseeds reported the positive significant growth rate. The study found also that all grain crops undergone instability in area, production and productivity with highest instability in wheat, maize and rice. It shows that the area was the main contributor of change in production of grain crops during reform.

Generally speaking, the agricultural reform has tremendous positive impact on growth rates of grain crops in Rwanda. However, there is a main question to ask: "Is this growth sustainable if the sole current policies, strategies and programs applied during reform continued to be use?" The answer would be seen through the mirror of this study: the cultivated area was generally the main contributor of production change, and the grain crops which showed highest growth rates in production recorded also high growth in cultivated area. Moreover, the current small arable land per household farmer would likely continue to shrink following the pace of rapid population growth and urbanization. The great number of population would likely have a negative effect on per capita production and high demand of grain crops. Therefore, if the current yield trends continue, the growth in crops production will decline overtime because of the limitations on land growth potential. Thus, the efforts have to be directed toward further increasing the productivity of various grain crops. The future government policies, strategies and programs should strengthen research of developing new high yielding varieties for all grain crops, specific to the agro-ecological conditions of the regions. Adopting and applying biotechnology in agriculture and using new efficient technology would be a solution to produce more using a small land.

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Appendix 1. Policy reforms and Agriculture prioritization

Elaboration	Duration	Reforms	Prioritization of Agriculture
2000	2000-2020	Vision 2020	Consider agriculture as the principle source of economic growth by transforming into a productive, high value, market oriented sector with forward linkages to other sectors.
2001	2002-2005	The First Poverty Reduction Strategy Paper (PRSP)	Transform agricultural sector
2008	2008-2012	The First Economic Development and Poverty Reduction Strategy(EDPRS-I)	The implementation strategy for *Vision 2020*. increase economic growth, increase agricultural productivity focusing on releasing the productivity capacity of the poor
2013	2013-2018	Second Economic Development and Poverty Reduction Strategy (EDPRSII)	Raise agricultural productivity and ensure food security

Source: Compilation by authors from Nkunzimana *et al*. (2015)

Appendix 2. Agricultural Strategies, Policies& Programme in Rwanda (2000-2016)

Elaboration	Duration	Strategy, Policy & Program	Prioritization of Agriculture
2004	2004	National Agricultural Policy	Make Agriculture the pillar for economic growth
2005	2009-2012	The Strategic Plan for the Transformation of Agriculture-Phase II	Increase rapidly agricultural output and incomes with emphasis on export products under sustainable production systems and ensuring food security.
		National Rice Policy	Increase production & rice productivity
2006		Girinka Programme	Increase agricultural productivity: throughout milk, meat and manure
2007		Crop Intensification	Increase the national agricultural productivity
		National Seed Policy	Produce and put at the disposal of agricultural farmers quality seeds for increasing productivity
2008		Land Use Consolidation Policy	Increase the agricultural productivity by reallocating parcels of arable lands
2009		National Agriculture Extension Strategy	Increase, diversify, specialize and intensify agricultural production
2010	2010-2015	The Agricultural Mechanization Strategy	Raise the power inputs of farming activities through mechanization technologies
		Agriculture Gender Strategy	Improve gender equality in the agriculture sector
2011	2011-2016	National Post-Harvest Staple Crop Strategy	Reduce staple crop post-harvest losses, improve consumer access to safe food
	-	The Purchase for Progress initiative	Encourage farmers to increase production by providing market for farm produce.
	-	Rwanda Commodities Exchange Market	Link with exchanges of other East African Community member states via import-export
2013	2013-2018	The Strategic Plan for the Transformation of Agriculture-Phase III	Transform agriculture from subsistence to commercial level

Source: Compilation by authors from Alinda and Abbott (2012); Nkunzimana *et al*.(2015)