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Contribution of Marshland Development on Rice Production in Rwanda

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Abstract

Rice is a most preferred food in rural and urban areas in Rwanda. The aim of this study was to analyze the contribution of marshland development on rice production in Rwanda, case of Rugende Marshland. The Authors based on hypotheses stating that there is no significant contribution to Rwanda rice production from Rugende marshland development project, and there is a significant contribution to Rwanda rice production resulting from Rugende marshland development project. This study used times series datasets of rice production collected from published Seasonal Agricultural Surveys (SAS) reports of the National Institute of Statistics of Rwanda (NISR) considered as baseline data. The Authors also employed the data collected from Rugende marshland rice farming cooperative formally registered in Rwanda Cooperative Agency (RCA) since April 19, 2018. Thereafter, the inferential statistics techniques such as linear regression, Correlation and Student's "t" test were used throughout the Statistical Package for Social Sciences (SPSS) to compute the regression coefficients (α and β) and Pearson Correlation (r) for the analysis of findings. The correlation analysis revealed that there is a low correlation ($0.25 \leq r < 0.50$) between sample dataset of Rugende paddy rice yield and national paddy rice yield, (Pearson correlation coefficient $r = 0.395$). The Student's t test accepted the research hypothesis that there is no significant difference between national and Rugende marshland rice crop yield. This results lead to the conclusion that about 100 hectares of developed marshland leads to the contribution of 0.5 percent on national paddy rice production, in the same condition of agricultural technology. The government was recommended to provide sufficient improved rice seeds, increase training to rice farmers and conduct rice varieties to be grown on hillside.

Keywords

Marshland Development, Irrigation, Rice Production, Rugende, Rwanda

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1. Introduction

In marshlands known as rice fields, water is often ponded to ensure that there is plenty for the rice crop to take up. Paddy rice production must be viewed in the light of the emerging water crisis, as climate change caused shifts in rainfall patterns combined with the diversion of irrigation water for urban and industrial uses. As agricultural water scarcity increases, there is a growing need for water saving technologies [1].

In South-East Asia, Myanmar (Burma Country) government has made a vast investment in the construction of dams to improve crop productivity and ensure socioeconomic development of its farmers. Due to the improvement in production capacity and gross output, the income of paddy farmers increased. It was noted that after the construction of dam, the change in farmer's income was observed with an average increase of about 3 times higher in all the water users. The study results revealed that an average monsoon paddy yield of 3084 kg per hectare of paddy crop was found before the dam project and an average monsoon paddy yield of 3293 kg per hectare was observed after the dam project [2].

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Historically, Sub-Saharan African governments have played a central role in irrigation development. Like their Asian counterparts, African countries received significant donor support from the World Bank and its partner lenders starting around the mid-1960s, when the Green Revolution was in full swing in Asia and irrigation was seen as a major strategic tool in the combat against poverty and food insecurity. The irrigation schemes established during this time were largely centralized, government-controlled systems that were designed without farmer input and without robust plans regarding their operation and maintenance [3].

The results of the study conducted in Ghana in 2018 revealed that irrigation farmers are richer than rain fed farmers and this is significant at 1%. Yield is an important variable in assessing farm level performance and it is evidently clear that irrigation farmers have higher yields than their rain fed farmer colleagues with mean difference of 681.26kg per acre. The total output of irrigation farmers was far more than the output of rain fed farmers with a mean of about 1823.29kg of paddy rice [4].

Moreover, rice is the most preferred food in rural and urban areas of Rwanda [5, 12, 16]. The results of National Institute of Statistic of Rwanda of 2019 revealed that the average productivity of rough rice was 4 tonnes per hectare [6].

Generally, rice crop is the only cereal that can stand in water submergence, and this helps to explain the long and diversified linkages between rice crop and water. For hundreds of years, natural selection pressures such as drought, submergence, flooding, and nutrient and biotic stresses led to a great diversity in rice ecosystems [7]. Therefore, pot experiments and greenhouse studies carried out at the International Rice Research Institute (IRRI) have shown that rice plants growing under a range of water applications transpired 500–1,000 liters of water to produce 1 kg of rough (unmilled or paddy) rice [1].

In Rwanda, the projects such as Rural Sector Support Project (RSSP) involved in marshlands rehabilitation and irrigation facilities and Land Husbandry, Water Harvesting and Hillside Irrigation (LWH) have been implemented with support of the World Bank (WB) and other donors in order to implement sustainable agriculture [8].

LWH has registered tremendous progress in increasing productivity and profitability of hillside agriculture across the country, both in irrigated and non-irrigated hillsides. The project benefited and transformed the livelihoods of more than 280,000 people and is considered as one of the most successful projects in Rwanda and in the region [9].

In line with the implementation of hillside irrigation and marshland development projects for sustainable agriculture, the Ministry of Agriculture and Animal Resources (MINAGRI) through Rural Sector Support Programme (RSSP) for marshland development, the World Bank financed the third Rural Sector Support Project (RSSP3) for the construction works of an 11m height dam and irrigation infrastructures at Rugende marshland for the execution period of two years, 2016 and 2017 [10].

The Third Rural Sector Support Project was part of a three-phase adaptable program loan (APL), aiming to help the Government of Rwanda (GoR) to implement national agriculture policy.

An urgent priority for Government to address its structural food deficit and increased share of marketed production was the development for irrigation of 60,000 ha of marshlands, along with the sustainable development of surrounding hillsides. Indeed, yields for rice, which is the main crop cultivated in the irrigated marshlands, increased from about 4 tons/ha, at baseline, to about 5 tons/ha at Project closing. In contrast, the national average was 3 tons/ha at appraisal and 3.4 tons/ha at Project closing [11].

Although rice is not a traditional crop in Rwanda among others, the characteristics of rice grains such as long shelf life, ease of cooking and transportation, and less requirement of cooking fuel (compared to traditional food such as potato and cassava) has made rice in becoming a popular choice of food in schools, homes, restaurants, and public ceremonies in Rwanda. Rise in income levels, growing population, and changing lifestyles have aggravated the demand for rice, which pushed that the Government of Rwanda to declare rice as a priority crop in 2002 [12]. According to the Food and Agriculture Organization the paddy rice annual production was expanded rapidly, reaching 95,000 tonnes by 2015, due largely to land expansion in Rwanda, and the yields oscillated around 5.5 tonnes per hectare from 2011 on [13].

The agricultural investments focused majorly on reclaiming marshlands to increase area under rice production, building drying and storage facilities, putting-up systems to ensure sustainable access to water for irrigating in paddy fields, quality seed production and research, setting-up rice factories to attract private investors in rice milling business, and capacity building of farmers to modern rice farming and post-harvest processing [14].

It has noted that Rwanda annually imported an average of 26,736 tonnes of milled rice by 2010. Furthermore, the quality of locally produced rice lagged behind that of imported rice. Thus, Rwanda's rice sector was confronted with how to sustainably raise both the production and quality of locally grown rice to meet the consumer demands [15, 16].

In fact, rural households in Rwanda spent annually more money (30,400 RWF) than the urban households (20,660 RWF) on rice consumption, as indicated by MINAGRI in 2013. Although both the rural- and urban households consumed imported rice, about 65.5% of the rice purchased by rural households was locally produced; and in contrast, about 62% of the rice purchased by urban households was imported [16].

However, in 2018 the domestic production was able to provide only 75% of the national annual requirement. The deficit was met through importation of milled rice from abroad. With rapidly increasing consumer demand for rice, Rwanda would have to produce 204,000 tons of milled rice by 2018, through marshland development and rehabilitation [12]. At National level, the Rural Sector Support Projects (RSSP 1 and 2) for marshland development rehabilitated 6,440ha of marshlands with the following achievements:

1) Marshlands have supported more than 50,000 farmers
2) Paddy rice yield increase from 3 to 6 tons per ha
3) Farmers' incomes tripled for the previous phases beneficiaries
4) Use of fertilizer increased from 34% to 86% in the project areas
5) Marshland farmers sell over 70% of their produce (nearly double the national average).
6) Over 70% of the supported coops doubled their incomes
7) 80% of the farmers opened their saving account, over 45% contracted loans
8) Poverty was almost halved for beneficiaries; from 65.6% to 39.3% [17].

Basin irrigation is suitable for many field crops. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method to use for this crop production [18]. However, there has been no specific study conducted to assess the contribution of Rugende marshland to national rice production after its development project completion in 2017. Therefore, the authors conducted such analysis in order to analyze the trends of rice production in Rugende marshland and evaluate its contribution to rice production in Rwanda. This study displays the accurate data on newly developed marshland for paddy rice growing area productivity and contribution to national paddy rice production and poverty reduction strategies.

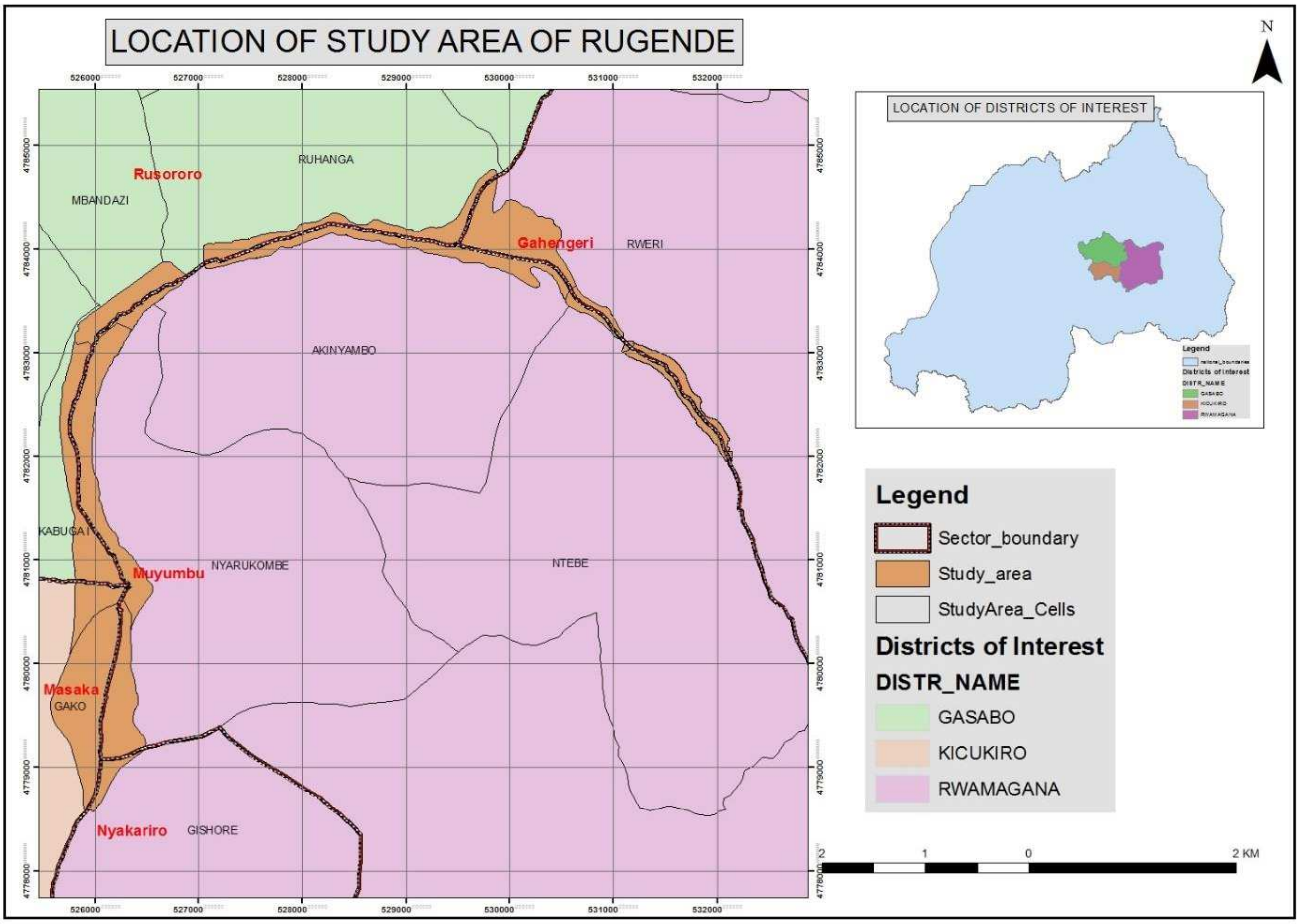

Figure 1. Map of Rugende Marshland.

2. Methods and Materials

2.1. Description of the Study Area

This study was conducted in Rugende marshland which covers five sectors shared by three districts. Three sectors include Gahengeri, Muyumbu, and Nyakariro sectors which are located in Rwamagana district of the Eastern Province. The marshland also is used by residents of Rusororo sector located in the Gasabo district and Masaka sector located in Kicukiro district, in the City of Kigali.

Table 1. Areas sharing Rugende Marshland.

Province	District	Sector	Cell
East:	Rwamagana	Gahengeri	Rweri
			Akinyambo
			Bujyujyu
		Muyumbu	Ntebe
			Nayarukombe
		Nyakariro	Gishore
			Kabuga I
Kigali City:	Gasabo	Rusororo	Mbandazi
			Ruhanga
			Ayabaraya
	Kicukiro	Masaka	Gako

Rugende marshland was developed in 2016 and 2017 as an initiative of improving its crop production and currently, rice is the main crop cultivated in this marshland. The EJO HEZA RUGENDE RICE cooperative is the cooperative cultivating rice in the marshland and is recognized by the Rwanda Cooperative Agency (RCA) since April 19, 2018 [19].

The marshland has the cropping area of 385 ha distributed in the following manner: 116 ha of rice cropping; 119 ha of vegetable crops and 150 ha fodder crops and livestock farming [10]. Thus, the researcher conducted an assessment on the contribution of marshland development project on rice production in Rugende marshland.

2.2. Data Collection and Analysis

This study used times series data of rice production collected from published Seasonal Agricultural Surveys (SAS) reposts of the National Institute of Statistics of Rwanda (NISR), and the data collected from Rugende marshland rice farming cooperative registered in Rwanda Cooperative Agency (RCA) as EJO HEZA RUGENDE RICE.

Baseline datasets of national rice production (Quantity of paddy rice, cultivated area, fertilizer inputs, and yields per ha) covering the agricultural ranging from season A of the year 2018 to season A of the year 2020. The study also employed the data of rice production after Rugende Marshland development Project from 2018, 2019 and 2020, in the same 4 seasons. In addition, the researcher conducted a site visit for the observations and field reality where the applied types of irrigation techniques and activities were identified and assessed.

Tools and Data Analysis

The tools of dataset collection were desk consultation of the published Seasonal Agricultural Surveys (SAS) reposts of the National Institute of Statistics of Rwanda (NISR), accessed from its website (www.statistics.gov.rw) on June, 2020. The physical interview and reports data records at EJO HEZA RUGENDE RICE head office. Thereafter, the inferential statistics techniques such as linear regression, correlation and Student's "t" test were used to compare the means of two group of samples (National rice production and Rugende marshland rice production datasets), coupled with computer application such as Statistical Package for Social Sciences (SPSS) to compute the regression coefficients (α and β) and Pearson Correlation (r) for the analysis of findings. Microsoft excel tables were also used in data editing, processing and coding. The results were published in the final report using Microsoft word format in both quantitative and qualitative terms.

Statistical data analysis

Computation of differences, rations, and growth on paddy rice production based on corrected data were calculated. In this study, the difference in production and consumption were considered as quantity sold on the market, while ratio between production and consumption was considered as a measure of rice preference in food consumption in Rwanda. The percentage of sold quantity of paddy rice was employed particularly to explore the quantity of production sold on market at the corresponding time. The following equations were employed.

$$D_{xy} = X - Y \tag{1}$$

$$R_{xy} = \frac{X}{Y} \tag{2}$$

$$\text{Percentage of sold quantity} = \frac{X-Y}{X}*100 \tag{3}$$

Where:

X: Quantity of produced paddy rice

Y: Quantity of paddy rice consumed by farmers at their household

D_{xy}: Difference of paddy rice production (X) and rice consumption by farmers household (Y) [20].

The seasonal gross return on investment form paddy rice production in Rugende marshland was calculated according to the unit price which varies by season and by seed varieties. The following equation was used:

$$Y = Q_x \text{ x } P_x \tag{4}$$

Where:

Y: stands for seasonal gross return on investment

Qx: stands for seasonal paddy rice production

P_x: The price of 1 kg or 1t of rough rice at harvest period.

The assessment on project viability was done by the computation of ratio of benefits to costs basing on current paddy rice yied earned by farmer from Rugende marshland. The following equation was used:

$$R_{BC} = \frac{B}{C} \qquad (5)$$

Where

R_{BC}: ratio of benefits to costs for paddy rice yield per hectare,

C: Cost of production of paddy rice on one hectare of cultivated land,

B: Benetit from production of paddy rice yield per hectare,

The regression equation is given by the following relation:

$$Y = \alpha + \beta x_i \qquad (6)$$

Where Y= Rice yield per hectare; x_i = Fertilizers inputs per hectare; in season (i)

α and β are regression coefficients or predictors [21].

3. Results

3.1. Project Activities for Rugende Marshland Development

The assumptions of Rugende marshland development project were subdivided into two aspects: (i) the construction of the dam, irrigation water reservoir and the irrigation infrastructures; (ii) the crop selection to be grown in Rugende marshland after being developed. The selected crops at command area of 385ha developed were rice at 116 ha, vegetables at 119 ha, and fodders crops for livestock at 150 ha.

3.1.1. Project Irrigation System

The irrigation system is composed by a gravitational irrigation for different crop cultivated at Rugende marshland. The system comprised the following components:

1) *The Earth Dam,* which consists of the dyke and reservoir. In this case, an earth embankment was used to impound and divert water from Rwamugeni River for irrigation purposes, served by a watershed of $34.5 km^2$.

2) *The command area,* which is downstream of the dam and the area irrigated. It is the part of the marshland area which in some areas was leveled, demarcated into plots and supplied with water from the reservoir by canals for intensive cultivation of crops like; rice, vegetables and fodders.

3) *Irrigation canals and drainage network,* which is the irrigation canals built as open earth canals along the immediate hillsides of the marshland. These irrigation canals consist of the primary canal that feeds the secondary canal that feed in the tertiary canals from which plantations are irrigated.

3.1.2. Characteristics of Project activities

The table 2 illustrates the characteristics of executed activities for together with geographical data of developed Rugende marshland.

Table 2. Characteristics of developed Rugende marshlad.

Irrigation infrastructures	Descriptions
Dam	
Latitude	1°57'43.74"S
Longitude	30°16'47.93"E
Design flood	100yr return period
Water catchment area	$34.5 km^2$
Average water in-puts in the dam	3.4 million m^3
Dam height from river bed	11 m
Crest elevation of dam	1384 m.a.s.l
Crest width	5 m
Crest length	150 m
Reservoir capacity	725,000 m^3
Reservoir coverage area	22 ha
Free board at 100yr design flood	1.5 m
Spillway at right side of dam	
Crest elevation of spillway	1382.50 m.a.s.l
Crest length	23 m
Maximum outflow	43 m^3/s
Water Intakes	
Intakes on the primary emissary (River Rwamugeni)	6 pc
Intakes on the secondary canals	52 pc
Irrigation canal	
Primary irrigation canals (combined left and right) banks)	25.4 km
Secondary irrigation canals (combined left and right) banks)	23.3 km
Tertiary irrigation canals	38 km
Drainage network	
Secondary Drainage network	24 km
Main crops and cover area	
Rice	116 ha
Vegetables	119 ha
Fodder crops for livestock	150 ha
Annual rainfall	992.6 mm
Number of rice farmers	439 farmers
Project Cost (in 2017)	3,000,000,000 RWF

Furthermore, the site visit and desk study revealed that Rugende marshland created permanent job for 439 farmers and many more casual labors from the surrounding sectors of Rwamagana, Kicukiro and Gasabo districts, throughout growing rice, vegetables and fodder crops since 2018.

3.2. The Trend of Rice Production from

Rugende Marshland

3.2.1. Analysis of Rice Crop Yield Per Hectare in Rugende Marshland

Apart from available irrigation water, labor, rice crop varieties, and capital and environmental factors (weather, flood, soil erosion…); this study analyzed the major factors of rice production used in Rugende marshland such as cultivated/harvested area and fertilizers inputs.

Table 3. Rugende Marshland Seasonal Rice Yield per hectare.

Season	Rice Production (Tonnes)	Used Fertilizers (Tonnes)		Cultivated area (ha)	Yield per hectare	Used Fertilizers per hectare (Tonnes)	
		NPK	Urea			NPK	Urea
2018B	397.702	17.500	8.750	107.000	3.717	0.164	0.082
2019A	425.178	19.050	9.550	116.000	3.665	0.164	0.082
2019B	500.529	19.200	9.050	116.000	4.315	0.166	0.078
2020A	443.331	17.800	10.000	116.000	3.822	0.153	0.086
AVERAGE	441.685	18.388	9.338	113.750	3.880	0.162	0.082

The results in Table 3 indicate that, after the completion of Rugende marshland development project in 2007, the average of rice production per season was 441.685 tonnes of unmilled rice grains in the past four seasons of rice harvest. The rice yield varies between 3.717 tonnes and 4.315 tonnes per hectare. The current average rice yield is 3.880 tonnes per hectare, while the average used fertilizer is 0.162 tonnes of NPK and 0.082 tonnes of Urea per one hectare of paddy field. The results in Figure 2 illustrate the variation of rice production in past four seasons.

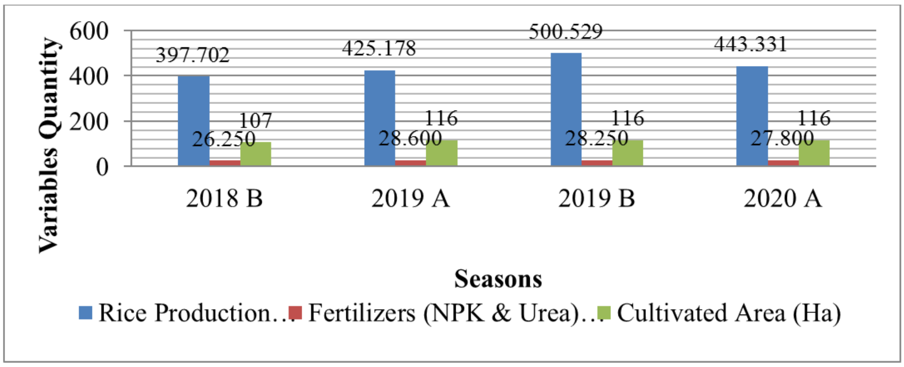

Figure 2. Rice crop Production in Rugende marshland, Source: Researcher, 2020.

The quantity of rice production varies by season. Considering the year 2019, in its season B, the rice production increased to 500.529 tonnes compared to 425.178 tonnes of season A. The agronomist working closely with Rugende paddy field explained that the reason of that increase is results of weather condition happened in that season. Normally the sunny season increases rice production in irrigated rice fields. Furthermore, the quantity of the used fertilizers decreased to 28.250 tonnes in season B, compared to 28.6 tonnes of fertilizers used in season A.

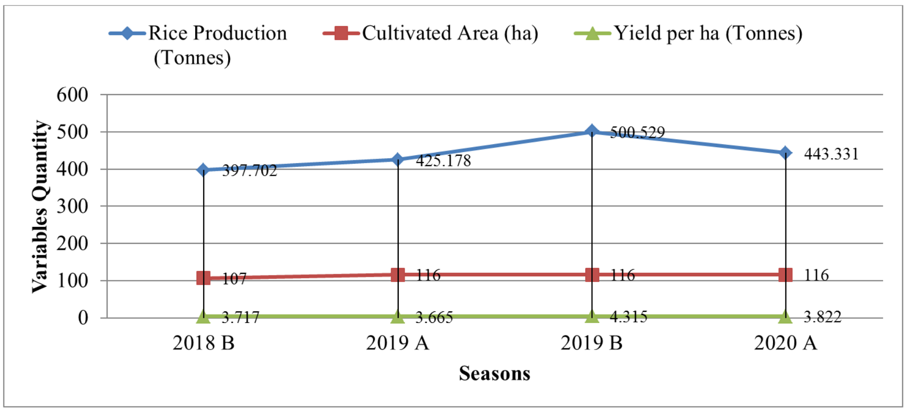

Figure 3. Rice crop yield in Rugende marshland, Source: Researcher.

Referring to the results in Figures 2 and 3, the opinion is that although the rice production trends to vary by seasons, the yield trends to be constant with the average turning around 3.88 tonnes per hectare and average fertilizers inputs is 0.244 tonnes per hectare.

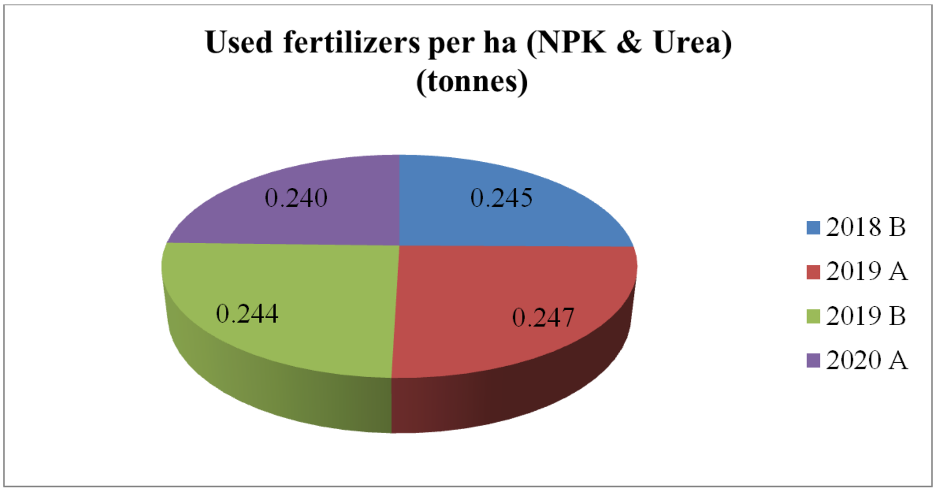

Figure 4. Used Fertilizers per hectare per season in Rugende.

3.2.2. Regression and Correlation Analysis

This analysis determines how the rice crop production in Rugende marshland is related to the cultivated area and fertilizers inputs. The assumption is that the rice crop yield depends upon the cultivated area and fertilizers inputs.

Table 4. Linear Regression.

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	9.285	17.008		0.546	.640	-63.893	82.464
	Fertilizers (NPK & Urea)	-22.154	69.700	-0.219	-0.318	.781	-322.050	277.742

a. Dependent Variable: Rice Production in Rugende marshland

$$Y= 9.285 – 22.154\ x_i$$

The Table 4 showed that all predictors, are not significant in the model, because all p-values (0.640 and 0.781) are greater than 0.05 (5%). The fertilizers perform less in rice yield in Rugende marshland.

Table 5. Correlation Coefficient (r) computation.

Correlations			
		Rice Production in Rugende marshland	Fertilizers (NPK & Urea)
Rice Production in Rugende marshland	Pearson Correlation	1	-0.219
	Sig. (2-tailed)		0.781
	N	4	4
Fertilizers (NPK & Urea)	Pearson Correlation	-0.219	1
	Sig. (2-tailed)	0.781	
	N	4	4

The formula for r is such that its numerical value always lies between -1 and +1.

Thus, when r = +1, there is a perfect positive linear correlation between X and Y variables.

When r = -1, there is a perfect negative correlation between X and Y variables.

When r = 0, there is no correlation between X and Y variables.

Moreover, the closer r is to +1 or -1, the closer the relationship between the variables,

and the closer r is to 0, the less the relationship.

In this section, the hypotheses to analyze are:

H_o: There is no significant relationship between rice yield and fertilizers inputs in Rugende marshland.

H_1: There is a significant relationship between rice yield and fertilizers inputs in Rugende marshland. Hence, r = -0.219. The conclusion is that H_1 is rejected and H_0 is accepted. There is less relationship between rice yield and use of fertilizers in Rugende marshland. Therefore, it can be noted that there is a contribution of other factors like irrigation, weather, pest control, seed variety etc… Considering P-value for decision making: P-value $\leq \alpha$: Reject H_0 [22].

Therefore, 0.781 is greater than 0.05 (α=5%). H_0 is accepted.

3.2.3. Farmers Rice food Consumption and Return from Total Production

Table 6. Quantity of paddy rice supplied on market from Rugende Marshland.

Year /Season	Rice Seed	Total Rice Production (tonnes)	Consumed rice by farmers (tonnes)	Sold rice (tonnes)	Ratio of consumed and Produced Quantity	Percentage of Sold rice
2018B	Short grain	215.556	2.769	212.787	0.013	98.72%
	Long grain	182.146	16.129	166.017	0.089	91.15%
2019A	Short grain	268.250	13.846	254.404	0.052	94.84%
	Long grain	156.928	16.923	140.005	0.108	89.22%
2019B	Short grain	133.247	7.692	125.555	0.058	94.23%
	Long grain	367.282	23.076	344.206	0.063	93.72%
2020A	Short grain	51.073	0.000	51.073	0.000	100%
	Long grain	392.258	41.538	350.720	0.106	89.41%
Total		1766.740	121.973	1644.767	0.061*	93.10%

* Average ratio of consumed and produced paddy rice

In Rugende marshland, farmers grow short and long grains seeds varieties of rice. The short grain refers to local variety known as "Kigoli". The long grains grown at Rugende marshland comprise two varieties: "Buryohe and Fashingabo".

Regarding the consumption of paddy rice production, 6.9% of total production is consumed by farmers households and 93.1% of paddy rice is supplied to market in other areas of the Country.

Table 7. Rugende Marshland Return from Rice Production.

Year /Season	Rice Seed	Total Rice Production (tonnes)	Unit Price (RWF)	Gross Return from total production (RWF)	Seasonal Gross Return from total production (RWF)
2018B	Short grain	215.556	305,000	65,744,580	123,120,570
	Long grain	182.146	315,000	57,375,990	
2019A	Short grain	268.250	270,000	72,427,500	117,936,620
	Long grain	156.928	290,000	45,509,120	
2019B	Short grain	133.247	255,000	33,977,985	134,980,535
	Long grain	367.282	275,000	101,002,550	
2020A	Short grain	51.073	315,000	16,087,995	133,765,395
	Long grain	392.258	300,000	117,677,400	
Total		1766.740	290,625*	509,803,120	509,803,120

*Computed average paddy rice price by 1 tonne

The results in table 7 showed that the current gross return from Rugende marshland rice production worth Rwandan Francs 509,803,120. The price varied from 255 RWF to 315 RWF.

The average paddy rice price by 1 tonne is Rwandan francs two hundred ninety thousand six hundred twenty five (290,625 RWF).

3.2.4. Cost Benefit Analysis on Rugende Rice Yield Per ha

Table 8. Computation of production cost and benefit from 1 ha of paddy rice.

Descriptions of activity	Cost in RWF
A. Production Cost	
Land preparation	225,000
Buying Seeds	15,000

Descriptions of activity	Cost in RWF
Buying Fertilizers	77,500
Weeds control	200,000
Buying Pesticides	82,500
Birds control	50,000
Harvesting works	60,000
Pay irrigation water fees	20,000
Pay land tax fees	20,000
Pay Cooperative contribution fees	23,280
Total Cost	773,280
B. Income from Paddy rice yield	
Average yield (3.88t) x Average price (290,625 RWF)	1,127,625
C. Benefit	
Income - Cost of production (B-A)	354,345

The results in Table 8 indicated that the seasonal average net benefit form paddy rice on 1 hectare in Rugende marshland is worth Rwandan francs three hundred fifty four thousands and three hundred forty five (354, 345 RWF). The ratio of benefit to cost stands currently on 0.46.

3.3. Rugende Marshland and National Rice Production

3.3.1. Seasonal Paddy Rice Production

Table 9. National seasonal rice production 2018 – 2020.

Season	Cultivated Area (ha)	Harvested Area (ha)	Rice Production (Tonnes)	Yield of Rice Crop (Kg/ha)
2018 B	15,842	15,842	55,946	3.531
2019 A	14,671	14,671	59,286	4.041
2019 B	18,225	18,225	72,291	3.967
2020 A	14,507	14,507	52,225	3.600
Average	15,811	15,811	59,937	3.785

The results in the table 9 illustrate that average national paddy rice yield from 2018 to 2020 is 3.785 t/ha. The results in Figure 5 below indicated that rice crop yield per ha in Rugende marshland is higher than national rice crop yield.

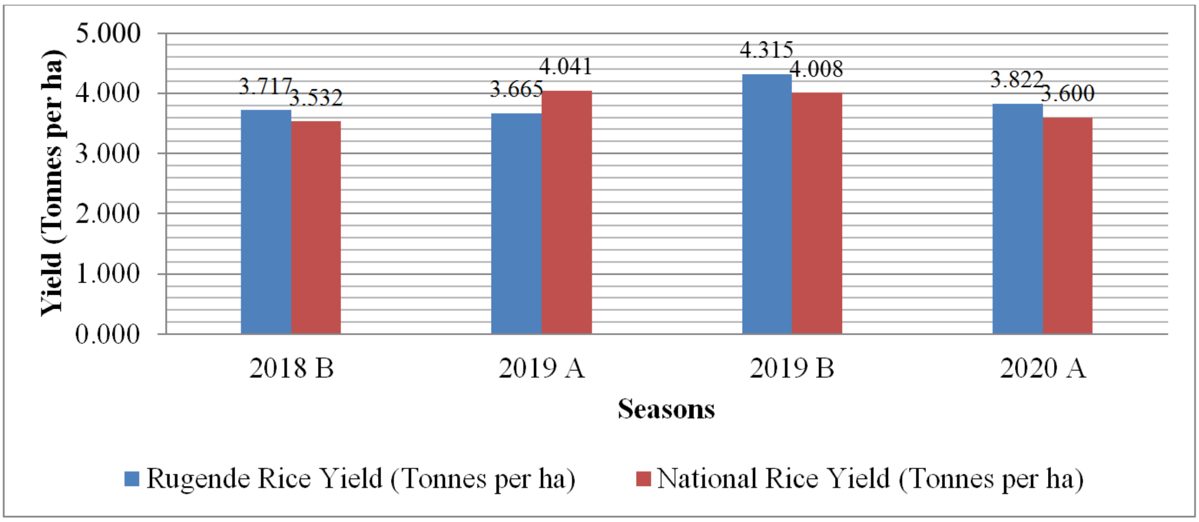

Figure 5. National and Rugende marshland rice crop yield per hectare.

3.3.2. Student "t" Test for National and Rugende Marshland Rice Crop Yield

The third test was made to test the following hypotheses in this section:

H_o = There is no significant difference between national and Rugende marshland rice crop yield

H_1 = There is significant difference between national and Rugende marshland rice crop yield.

Table 10. Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Rugende Rice Yield (Tonnes per ha)	3.87975	4	0.297424	0.148712
	National Rice Yield (Tonnes per ha)	3.79525	4	0.266508	0.133254

The results presented in table 10 show that the mean and standard deviation of Rugende marshland rice yield are greater than the mean and standard deviation of national rice yield.

Table 11. Paired Samples Correlations.

		N	Correlation	Sig.
Pair 1	Rugende Rice Yield (Tonnes per ha) & National Rice Yield (Tonnes per ha)	4	0.395	0.605

When: r =1 =perfect correlation

$0.75 \leq r < 1$; very high correlation

$0.50 \leq r < 0.75$; high correlation

$0.25 \leq r < 0.50$; low correlation

$0 < r < 0.75$; very low correlation

r=0 = no correlation

So, the correlation coefficient "r" is 0.395. H_0 is accepted.

H_o = There is no significant difference between national and Rugende marshland rice crop yield

Table 12. Paired Samples "t" test computation.

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Rugende Rice Yield (Tonnes per ha) - National Rice Yield (Tonnes per ha)	0.084500	0.311220	0.155610	-0.410720	0.579720	0.543	3	0.625

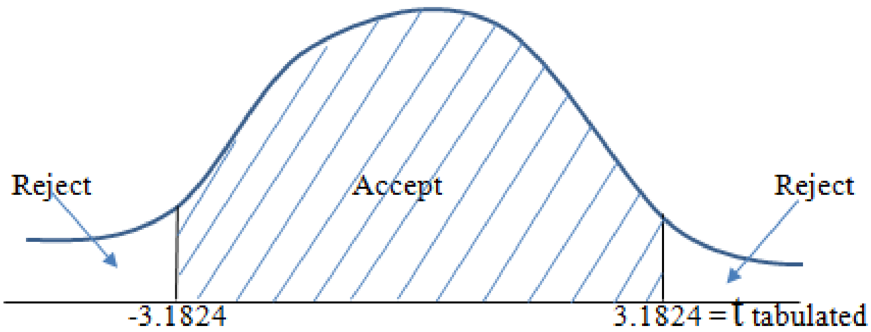

Figure 6. Student's t value distribution.

In the table 12, t calculated value is 0.543, P-value is 0.625 and the degree of freedom is 3, the significance level α=0.05 (5%).

When: P-value ≤ α; H_0 is rejected

Therefore, 0.625 is greater than 0.05 (α=5%). Hence, H_0 is accepted.

H_o = There is no significant difference between national and Rugende marshland rice crop yield.

When: t-calculated > t-tabulated; H_0 is rejected

Therefore, 0.543 is smaller than 3.1824 (By student's t distribution table). Hence, H_0 is accepted.

H_o = There is no significant difference between national and Rugende marshland rice crop yield

3.3.3. Annual Paddy Rice Production

The results presented in table 13, show that the national average annual paddy rice production from 2018 to 2020 is 99,227 tonnes of paddy rice, whereas Rugende marshland produced annual average of 588.913 tonnes, which represent the contribution of 0.593 percent at national annual paddy rice production.

Table 13. Rugende and national paddy rice production from 2018 to 2020.

Period	Rugende Paddy Rice Production (Tonnes)	National Paddy Rice Production (Tonnes)	Percentage
2018	397.702	113,880	0.349%
2019	925.707	131,577	0.704%
2020	443.331	52,225	0.849%
AVERAGE	588.913	99,227	0.593%

4. Discussion

The study findings revealed that marshland have been developed in years 2016 and 2017 as reported by MINAGRI [10]. The findings indicated that the first paddy rice production was recorded in cooperative book since season B of year 2018. The surface irrigation was applied to irrigate command area for paddy rice production [18]. In Rugende marshland the applied development activities consisted of 11m height earth dam to make irrigation water reservoir of 725,000 m^3, construction of irrigation facilities and digging primary, secondary and tertiary canals. Finally, the leveling and drainage system of irrigation command area of 385ha developed for rice at 116 ha, vegetables at 119 ha, and fodders crops for livestock at 150 ha. However, natural selection pressures such as drought, submergence, flooding, and nutrient and biotic stresses led to a great diversity in rice ecosystems [7]. Nevertheless, despite many rice seeds varieties developed in Rwanda, Rugende rice farmers are still growing only local varieties such as short grains (Kigoli) and long grains (Buryohe and Fashingabo).

For the fact of rice ecology, the International Rice Research Institute (IRRI) revealed that rice plants growing under a range of water applications require 0.5 m^3 – 1.0 m^3 of water to produce 1 kg of rough paddy rice. Rugende marshland has enough water for paddy rice production in two seasons of a year, due to constructed water reservoir capacity which is an alternative solution to agricultural dependence and vulnerability to climate change. The current average seasonal production of Rugende marshland is 441.685 tonnes of paddy rice harvested on developed area of 116 ha.

According to the Food and Agriculture Organization [13], the paddy rice annual production was expanded rapidly, reaching 95,000 tonnes by 2015, due largely to land expansion in Rwanda, and the yields oscillated around 5.5 tonnes per hectare from 2011 on. The investments were focused majorly on reclaiming marshlands to increase area under rice production, building drying, storage facilities and putting-up systems. These efforts helped to ensure sustainable access to water for irrigating in paddy fields, quality seed production and research, setting-up rice factories to attract private investors in rice milling business, and capacity building of farmers to modern rice farming which led to the increase in rice production in Rwanda reaching 115,315 tonnes in 2018. Farmers were organized in cooperatives and almost 40 improved varieties yielding more than 7 tonnes per hectare were availed to rice producers [14].

However, the results of the National Institute of Statistic of Rwanda report of 2019 on Seasonal Agricultural Survey (SAS) indicated that the average productivity of paddy rice was 4 tonnes per hectare [6]. Furthermore, the computed average national paddy rice yield from NISR datasets dating from 2018 to 2020 is 3.785 tonnes per hectare. World Bank report of 2019 revealed that in Rwanda, the yields for paddy rice which is the main crop cultivated in the irrigated marshlands, increased from about 4 tons/ha, at baseline, to about 5 tons/ha at Project closing. But in contrast, the national average was 3 tons/ha at appraisal and 3.4 tons/ha at Project closing [11]. This is not far from the results of this study, where the average seasonal paddy rice yield in Rugende marshland is 3.880 tonnes per hectare.

In 2010, Rwanda annually imported an average of 26,736 tonnes of milled rice [15]. It would have to produce 204,000 tonnes of milled rice by 2018, through marshland development and rehabilitation [14]. The results from SAS datasets of NISR referred in this study showed that the national average annual paddy rice production from 2018 to 2020 is 99,227 tonnes of paddy rice. Rugende marshland produced 588.913 tonnes, which represents the contribution of 0.593 percent of national annual paddy rice production.

In South-East Asia, It is observed that after the construction of dam, the change in farmer's income was observed with an average increase of about 3 times higher in all the water users [2]. This is supported by this study, where indicated that the seasonal average net benefit form paddy rice on 1 hectare in Rugende marshland is worth Rwandan francs three hundred fifty four thousands and three hundred forty five (354, 345 RWF). This is an extra income added on previous agricultural income from other crops grown in the surrounding area.

The study done by MINAGRI in 2013 revealed that rural households spent annually more money (30,400 RWF) than the urban households (20,660 RWF) on rice [16]. The results of this study shows that 6.9 percent of the average total annual paddy rice production in Rugende marshland is consumed by farmers. This is worth to 6.9 percent (35,176,415 RWF) of gross return (509,803,120 RWF) from paddy rice production. Among 439 farmers, one farmer consumes the quantity of rice averaged at 80,128 RWF every year at his household.

5. Conclusion

The correlation analysis revealed that there is a low correlation ($0.25 \leq r < 0.50$) between sample dataset of Rugende paddy rice yield and national paddy rice yield, (Pearson correlation coefficient r = 0.395). The Student's t test accepted the hypothesis; H_o: There is no significant difference between national and Rugende marshland rice crop yield. Furthermore, the findings revealed that the national average annual paddy rice production from 2018 to 2020 is 99,227 tonnes of paddy rice, whereas Rugende marshland produced 588.913 tonnes, which represents the contribution of 0.593 percent of national annual paddy rice production. This results lead to the conclusion that about 100 hectares of developed marshland leads to the contribution of 0.5 percent on national paddy rice production, in the same condition of agricultural technology. The current study indicated that an increase of 1 centigrade of nation rice production requires a development of 200 hectare of new paddy field. The government was recommended to provide sufficient improved rice seeds, increase training to rice farmers and conduct rice varieties to be grown on hillside. Further studies are suggested to conduct a comparative study on the irrigation ecology of rice varieties on rice production efficiency in Rwanda, in order to achieve the target of 7 tonnes per hectare of rice productivity.

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Conflict of Interest

The Author declares no conflict of interest.

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