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DETERMINANTS OF YIELD GAP IN RAINFED AND IRRIGATED RICE PRODUCTION SYSTEMS – EVIDENCE FROM HOUSEHOLD SURVEY IN KWARA STATE, NIGERIA

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Abstract. The actual yield of rice in Nigeria has not been able to reach its potential. Consequently, the cost of rice importation is alarming. However, rice yield varies under various production systems. Therefore, this study examines the determinants of yield gap in rainfed and irrigated rice production systems in Kwara state, Nigeria. Gross Margin Budgetary analysis, Stochastic Frontier, and Linear Regression Model were respectively used to estimate the profitability, technical efficiency, and determinants of yield gap in both production systems. The result shows that rice production is more profitable and efficient under the irrigated rice production system than the rainfed rice production system. It was also discovered that the significant determinants of yield gap in both production systems vary. However, the size of farm cultivated and the rice variety planted are common significant determinants of yield gap in both systems. This research therefore recommends that irrigation facilities and improved rice variety should be made available to farmers. Additionally, policy makers should formulate policies that would enable rice farmers to have access to larger farm lands.

Keywords: yield gap, irrigation, production systems, rice

INTRODUCTION

Rice is a staple food for more than 3.5 billion people worldwide; around half of the world's population (IRRI, 2013). Rice is an increasingly important crop in Nigeria and has been found to thrive under four main ecologies suitable for different rice varieties. These are: rainfed upland, shallow swamps and inland valley swamps (rain-fed lowland), irrigated lowland, and mangrove or tidal swamp ecology (Imolehin and Wada, 2005). Nigeria is known to have comparative resource advantage in terms of favourable climatic, edaphic, and ecological conditions in the production of rice for self-sufficiency (Imolehin and Wada, 2005).

Yield Gap is the difference between potential and actual yields. The actual yield of rice in Nigeria is not up to its expected potential yield. This explains why the importation of rice in to the country is at an alarming rate. The level of domestic rice production in Nigeria is estimated to be around 3 million metric tons while the domestic demand for rice is around 5 million metric tons which has led to a huge demand – supply gap of around 2 million metric tons of rice annually, thereby motivating the continued dependence on importation to fill the existing gap (Daramola, 2005).

Nigeria ranks second largest importer of rice in the world, spending about N356 billion for about 2 million MT of milled rice. Although the country is the largest producer of rice in West Africa, it still accounted for up to 20 per cent of sub-Saharan Africa's rice imports for domestic consumptions (Omotola and Ikechukwu,

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2006). The importation of rice to bridge the demand-supply gap is worth N365 billion (Ayanwale et al., 2011). The implication of which is a loss of considerable foreign exchange for the country which could be utilized for other needs. Imported rice has affected the domestic production and marketing of Nigeria's local rice. This is due to the decreased demand for local rice by Nigerians as opposed to the imported ones. The local Nigerian variety has a lower demand due to poor processing compared to the imported rice (Bamba et al., 2011).

Rice yields are between 46% and 56% below their potential for different production systems (Cadoni and Angelucci, 2013). Irrigated rice is the best performing in terms of yields (3.5 tonne/ha), followed by rainfed lowland (2.2 tonne/ha) and mangrove swamp (2 tonne/ha) (Cadoni and Angelucci, 2013).

The International Fertilizer Development Centre (IFDC), in the year 2008 estimated that given the average National yield of 0.96 MT/ha, Nigeria would need to devote additional 2.6 million hectares of harvest area to achieve self-sufficiency. Alternatively, if current productivity could be raised to the world average of 4.1 MT/ha, the resulting production within Nigeria would increase to 15.2 million metric tons of rough rice, equivalent to 10.2 million metric tons of milled rice. As a result, this would provide Nigeria with enough milled rice to feed its own domestic consumption needs, and to meet virtually all of the import needs of the remainder of Sub-Saharan Africa.

On a more practical level, if Nigeria could achieve the world average yield of 4.1 MT/ha on the 630,000 ha irrigated segment of its production, rice production would increase by 1.7 (rough rice) or 1.1 (milled rice) million metric tons. At this level of productivity, 214,000 additional ha of irrigated production would be enough to achieve self-sufficiency (IFDC, 2008).

Technical efficiency is defined as a measure of how well an individual transforms inputs into a set of outputs based on a given set of technology and economic factors. Despite the various policy measures, domestic rice production has not increased sufficiently to meet the increased demand. Nigeria has comparative resource advantage, in terms of favourable climate, edaphic, and ecological conditions with about 4.8 million hectares of potential land area for rice production to be self-sufficient in the production of the commodity. However, the country depends extensively on importation (Ilevbaoje and Ingawa, 2008). The question of "could it be that the rice farmers are not efficient in the use of resources?" readily comes to mind.

The present dichotomy between the actual and potential yield of rice which led to increased importation forms the thrust of this study. Thus, this research examines those factors that determine the yield gap in both irrigated and rainfed rice production systems in Kwara state. The specific objectives are to; estimate the Profitability of rice production under rainfed and irrigated rice production systems in the study area; determine the technical efficiency of the rice farmers in the study area and to; assess the determinants of yield gap in both production systems;

METHODOLOGY

The study area

This study was carried out in Kwara State, Nigeria. Kwara State is in North central Nigeria. Kwara State is situated between parallels 8° and 10° North latitudes and 3° and 6° East longitudes, with Niger State in the north, Kogi State in the east, Oyo, Ekiti and Osun States in the south and an international boundary with the Republic of Benin in the west.

The state is divided into four Agricultural Zones by the Kwara State Agricultural Development Project (KWADP) authority based on agro-ecological considerations. Although rice is produced in all the KWADP Zones, the KWADP Zone B produces about 90 percent of the state's annual rice production. Kwara State's annual rice production estimate ranges between 17.5–118.3 metric tonnes: 49.6 metric tonnes on average (KWADP, 2004). The target population for this study is those farmers that produce rice, in the study area.

Sampling technique

A three stage sampling procedure was adopted to select a representative sample for the study. The first stage comprised the purposive selection Edu and Patigi Local Governments in Zone B of Kwara Agricultural development project (KWADP) because they are representative zone for rice production in Kwara State, followed by a random selection of 20 villages each from the two Local Governments. The third stage involves the random selection of 10 households across the selected villages making a total of 200 respondents.

Analytical techniques

Gross margin and profitability index: these were used to estimate the profitability of rice production under rain fed and irrigated rice production systems in the study area. They are specified as follows:

$$\text{Gross Margin (GM)} = \text{TR} - \text{TVC}$$

where:

GM = Gross Margin (N/ha)
TR = Total Revenue (N/ha)
TVC = Total Variable Cost (N/ha)

Stochastic frontier: This was employed to measure the technical efficiency level of the farmers. The empirical specification of function is given as below:

$$Y_i = X_{ij}\beta_j + (v_i - u_i) \text{ that is, } \varepsilon_j = u_j + v_j$$

Where, 'i' stands for ith farm and 'j' stands for jth input and β0 and βj denote intercept and coefficients of different variables respectively.

Y = yield gap
X_1 = farm size
X_2 = quantity of seed
X_3 = herbicides
X_4 = urea nutrient/farm
X_5 = labour hours/farm
X_6 = plant protection/pesticide quantity
X_7 = NPK, nutrients/farm
β_j is a vector of k unknown parameters,
ε_i is an error term = $V_1 + U_1$
V_i = random error
U_i is technical inefficiency effects which are independent of V_i.

The mean of farm specific technical inefficiency U_i is defined as:

$$U_I = \sigma_0 + \sigma_1 z_{1i} + \sigma_2 z_{2i} + \sigma_3 z_{3i} + \sigma_4 z_{4i} + \dots \quad (2)$$

where:

Z_1 is age of farmer, a priori expectation is positive.
Z_2 is educational level of farmers, a priori expectation is negative.
Z_3 is household size, a priori expectation is negative.
Z_4 is experience of farmer, a priori expectation is negative.
Z_5 is the contact with extension agent
Z_6 is the number of different rice plots

Linear regression model: This was employed to analyze the determinants of yield gap in both systems of rice production.

Model specification for the linear regression:

$$Y = f(X_1, X_2, X_3, X_4, \dots, X_n)$$

Y = yield gap
X_1 = educational status
X_2 = experience in rice farming (years)
X_3 = household size (number of people)
X_4 = membership of association (0 = non-member; 1 = member)
X_5 = contact with extension agent
X_6 = number of rice plots
X_7 = amount labour (family) utilized
X_8 = amount labour (hired) utilized
X_9 = farm size/ha
X_{10} = fertilizer/ha (urea)
X_{11} = fertilizer/ha (NKP)
X_{12} = herbicides (litres)
X_{13} = pesticide (litres)
X_{14} = variety of seed planted (0 = traditional or local; 1 = improved)

RESULTS AND DISCUSSION

Table 1 presents the Gross margin analysis for both rainfed system and irrigated system. The estimate reveals that on average rain fed rice farmers makes a gross margin of N28,147 per ha. While an average irrigated rice farmer makes an estimated amount of N45,945 per ha. This conforms to the apriori expectation that irrigated rice farmers is more profitable compared to the rainfed system. It can be deduced that rice cultivation is quite lucrative in the study area.

Technical Efficiency of Rice Farmers in the study area

Table 2 shows the distribution of technical efficiency among the respondents, which reveals that there is great variation in the levels of efficiency among the farmers which ranges from 41.1% to 97.8% with a mean of 83.0% for farmers under rainfed system while the range is between76.8% to 98.3% with a mean of 92.7% for farmers under irrigated system. The mean level of technical efficiency indicates that on average rice output falls 17.0% short of the optimum output expected to be obtained per farmer. Therefore, in the short run it is

Table 1. Gross margin analysis for both rainfed and irrigated systems
Tabela 1. Analiza marży brutto w przypadku nawadniania naturalnego i sztucznego

Items Pozycje	Average costs of variable inputs (N/Ha) Średnie koszty zróżnicowanego wkładu (NGN/ha)	
	Rainfed system Nawadnianie naturalne	Irrigated system Nawadnianie sztuczne
Seedlings – Sadzonki	6,402.66	3,987.98
Fertilizers – Nawozy	14,134.34	16,591.32
Pesticides – Pestycydy	3,003.81	4714.82
Herbicides – Herbicydy	9,252.06	10,417.74
Labour – Robocizna	90,631.21	91,484.28
Tractor usage – Użycie traktora	6,835.30	6,998.5
Irrigation water – Woda do nawadniania	0.0000	4500
TVC – Łączne koszty zmienne	130,259.4	138,694.7
Returns – Zwrot		
Total Revenue – Łączny przychód	158,407.30	184,639
Gross margin – Marża brutto	28,147.88	45,944.91

Source: field survey, 2014.
Źródło: badania terenowe, 2014.

Table 2. Frequency distribution of technical efficiency of rice farmers
Tabela 2. Rozkład częstości poszczególnych przedziałów efektywności technicznej w przypadku producentów

Technical efficiency (TE) Efektywność techniczna (ET)	Rainfed system Nawadnianie naturalne		Irrigated system Nawadnianie sztuczne	
	Frequency Częstość	Percentage Procent	Frequency Częstość	Percentage Procent
0.401–0500	1	1	0	0
0.501–0.600	5	5	0	0
0.601–0.700	6	6	0	0
0.701–0.800	17	17	3	3
0.801–0.900	35	35	18	18
0.901–1.000	36	36	79	79
Total – Łącznie	100	100	100	100
Mean TE – Średnia ET	0.830	0.927		
Minimum TE – Minimalna ET	0.411	0.768		
Maximum TE – Maksymalna ET	0.978	0.983		

Source: computed from field data, 2014.
Źródło: obliczenia na podstawie danych zebranych w terenie, 2014.

Table 3. Yield gap estimation for the different rice varieties
Tabela 3. Oszacowanie luki w wielkości plonów dla różnych odmian ryżu

Rice variety Odmiana ryżu	Rainfed system Nawadnianie naturalne			Irrigated system Nawadnianie sztuczne		
	MPY	MFY	MYP	MPY	MFY	MYP
FARO 52	6 000	2 973	3 027	6 000	3 422	2 578
FARO 44	6 000	3 625	2 375	6 000	3 523	2 477
Traditional Tradycyjna	2 750	2 314	436	2 750	2 460	290
Total Razem	6 000	2 491	3 509	6 000	2 890	3 110

MPY – Mean potential yield, MFY – Mean farm yield, MYP – Mean yield gap.
Source: field data.
MPY – średnia potencjalna wielkość plonów, MFY – średnia wielkość plonów w gospodarstwach, MYP – średnia luka w wielkości plonów.
Źródło: dane zebrane w terenie.

possible to increase rice production in the study area by an average of 17.0 per cent by adopting the technology used by the average farmer or best performers.

Yield gap among the rice varieties planted under the two production systems

The mean yield gap that occurred due to technical inefficiency for each variety planted in the study area is presented in Table 3. This was achieved by finding the difference between the mean potential yield of a variety and the mean yield from the farmer's field. Under the rainfed system it was observed that the mean yield gaps were 3027 kg/ha, 2375kg/ha and 436 kg/ha for FARO 52, FARO 44 and the local or traditional varieties respectively. Under the irrigated system mean yield gaps were the 2578 kg/ha, 2477 kg/ha and 290 kg/ha for FARO 52, FARO 44 and the traditional varieties respectively.

Determinants of yield gaps

Table 4 indicates that factors such as: household size, amount of family labour, fertilizer (Urea), farm size, and variety planted all had significant effect on the magnitude of yield gap. Household size was found to be positively significant implying that the larger the household size the wider the yield gap. This might be because it serves as a source of family labour on the farm hence significant, while its positive effect on yield gap can be as a result of over utilization. The amount of family labour and fertilizer (Urea) used are negatively significant implying that the higher the amount of these factors (family labour and fertilizer (Urea)) used, the lower the yield gap. Farm size also has significant positive effect on the yield gap that is the larger the farm size, the higher the yield gap. This is in agreement with the theory that larger farm sizes are more efficient than smaller ones. The type of variety planted also has a significant positive effect on yield gap of rice. The positive influence here indicates the fact that improved varieties tends to wider yield gap than the local or traditional varieties. This result is probably due to farmers inability to meet up with the nutrient requirement/adoption of improved practices suitable to maximize yield.

Table 5 shows the result of the regression analysis for the determinants of yield gap in irrigated rice farms. It reveals that; farming experience, membership of association, farm size, and the type of variety planted all have a positive, significant influence on the magnitude of yield gap.

Table 4. The determinants of yield gap in rainfed rice production
Tabela 4. Uwarunkowania powodujące lukę w wielkości plonów osiąganych w nawadnianych naturalnie systemach produkcji ryżu

Variable Zmienna	Coefficients Współczynniki	Std Error Błąd standardowy	t-stat Statystyka t
Educational status Poziom wykształcenia	0.100	0.077	1.298
Rice farming experience Doświadczenie w uprawie ryżu	–0.007	0.007	–0.984
Household size Wielkość gospodarstwa	0.032**	0.013	2.451
Membership of Association Członkostwo w stowarzyszeniu	–0.310	0.210	–1.477
Extension visits Wizyty przedstawiciela agencji promującej stosowanie technologii	0.136	0.175	0.775
Number of plots Liczba działek	0.056	0.083	0.673
Amount labour (family) utilized Nakłady pracy (członków rodziny)	–0.002**	0.001	–2.363
Amount labour (hired) utilized Nakłady pracy (pracowników najemnych)	0.000	0.001	–0.508
Fertilizer/ha (urea) Nawozy/ha (mocznik)	–0.125***	0.035	–3.529
Fertilizer/ha (NKP) Nawozy/ha (azotowe, fosforowe i potasowe)	0.004	0.041	0.110
Herbicides (liters) Herbicydy (litry)	0.003	0.005	0.645
Pesticide (liters) Pestycydy (litry)	0.004	0.014	0.279
Farm size/ha Powierzchnia gospodarstwa (ha)	0.317***	0.040	7.998
Variety of seed planted Odmiana nasion	0.983***	0.161	6.119
Constant Koszty stałe	–361	0.472	–0.765
R^2	0.591		
F	8.78		
N	100		

* Significant at 10%, ** significant at 5%, *** significant at 1%.
Source: field survey, 2014.
* Zmienna istotna na poziomie istotności 10%, ** zmienna istotna na poziomie istotności 5%, *** zmienna istotna na poziomie istotności 1%.
Źródło: badanie w terenie, 2014.

Table 5. The determinants of yield gap in irrigated rice production
Tabela 5. Uwarunkowania powodujące lukę w wielkości plonów osiąganych w sztucznie nawadnianych systemach produkcji ryżu

Variable Zmienna	Coefficients Współczynniki	Std Error Błąd standardowy	t-stat Statystyka t
Educational status Poziom wykształcenia	–0.025	0.043	–0.596
Rice farming experience Doświadczenie w uprawie ryżu	0.010**	0.005	2.062
Household size Wielkość gospodarstwa	–0.012	0.008	–1.574
Membership of association Członkostwo w stowarzyszeniu	0.216**	0.102	2.113
Extension visits Wizyty przedstawiciela agencji promującej stosowanie technologii	–0.19	0.091	–0.206
Number of plots Liczba działek	0.004	0.082	0.046
Amount labour (family) utilized Nakłady pracy (członków rodziny)	0.000	0.001	–0.631
Amount labour (hired) utilized Nakłady pracy (pracowników najemnych)	0.000	0.000	0.620
Fertilizer/ha (urea) Nawozy/ha (mocznik)	0.007	0.022	0.310
Fertilizer/ha (NKP) Nawozy/ha (azotowe, fosforowe i potasowe)	0.017	0.013	1.319
Herbicides (liters) Herbicydy (litry)	0.003	0.003	0.794
Pesticide (liters) Pestycydy (litry)	0.009	0.009	1.039
Farm size (ha) Powierzchnia gospodarstwa (ha)	0.068**	0.024	2.900
Variety of seed planted Odmiana nasion	0.280**	0.090	3.113
Constant Koszty stałe	–1.024	0.344	–2.977
R^2	0.360		
F	3.410		
N	100		

* Significant at 10%, ** significant at 5%, *** significant at 1%.
Source: field survey, 2014.
* Na poziomie istotności 10%, ** na poziomie istotności 5%, *** na poziomie istotności 1%.
Źródło: badanie w terenie, 2014.

CONCLUSION AND RECOMMENDATIONS

From the results obtained, it was concluded that rice production in the study area is profitable despite there being a wide yield gap in the output obtained by the farmers. Rice production has a very large profit margin and could serve as veritable avenue for poverty alleviation to the youths possessing the socio-economic characteristics outlined above. Irrigated rice production system was more profitable than the rainfed one.

It was also revealed that farming experience, membership of association, farm size, and the type of variety planted all have a positive, significant influence on the magnitude of yield gap in rice production in the study area. This implies that they all widen yield gap in rice production in the study area. This may be due to the causes of inefficiencies such as low level of education, inadequate access to training particularly on the requirements of the improved rice varieties, and failures of farmers association.

It is therefore recommended that the efforts of stakeholders should be directed towards training and retraining of farmers on the adequate agronomic practices as well as nutrient requirement for each rice variety that is planted or proposed for planting in the study area. The farmers should also be supported with irrigation facilities as well as other farm inputs to aid their efficiency. There should be proper monitoring of farmers' associations by stakeholders as to prevent their failures and attendant consequences. Once the causes of inefficiencies of larger farms is controlled and farmers are empowered, policies that would allow them to have access to larger farm sizes should be put in place in order to make room for the production of larger quantity of rice in the study area.

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UWARUNKOWANIA POZIOMU PLONÓW RYŻU W UPRAWACH NAWADNIANYCH NATURALNIE I SZTUCZNIE – NA PODSTAWIE BADAŃ PRZEPROWADZONYCH W STANIE KWARA W NIGERII

Streszczenie. Rzeczywista wydajność produkcji ryżu w Nigerii odbiega od potencjału, jakim dysponuje ten kraj, przez co koszty importu tego zboża osiągają alarmujący poziom. Wielkość plonów waha się jednak w zależności od zastosowanego systemu produkcji. Niniejsze badanie dotyczy zatem uwarunkowań wydajności w nawadnianych naturalnie (deszczem) i sztucznie nawadnianych uprawach ryżu w nigeryjskim stanie Kwara. Do oszacowania rentowności, efektywności technicznej i uwarunkowań skutkujących niedostateczną wydajnością w obu systemach produkcji wykorzystano odpowiednio budżetową analizę marży brutto, stochastyczną analizę graniczną oraz model regresji liniowej. Jak pokazują wyniki, systemy produkcji ryżu oparte na sztucznym nawadnianiu charakteryzują się większą rentownością i efektywnością niż uprawy nawadniane naturalnie. Ponadto ustalono, że oba systemy produkcji różnią się pod względem istotnych uwarunkowań skutkujących luką w wielkości plonów. Zaobserwowano także uwarunkowania wspólne dla obu systemów – są nimi wielkość gospodarstwa rolnego i uprawiana odmiana ryżu. Na podstawie niniejszego badania można zatem zalecić, aby rolnikom zostały udostępnione urządzenia nawadniające i udoskonalone odmiany ryżu w odpowiednim zakresie i we właściwych terminach. Ponadto decydenci polityczni powinni opracować strategie, które umożliwią producentom ryżu dostęp do gospodarstw o większej powierzchni.

Słowa kluczowe: luka w wielkości plonów, nawadnianie, systemy produkcji, ryż

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