Agroecological Differentials in Crop Production: Evidence from Smallholder Rice Producers in Nigeria

Olorunfemi O. Ogundele[1] and **Temitayo A. Adeyemo[1*]**

[1]Nigerian Institute of Social and Economic Research
**Correspondence: adeyemotemitayo@gmail.com*

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Abstract

In the quest to sustain the current level of rice self-sufficiency and achieve export potential amidst challenges of climate change in Nigeria, irrigation farming has been encouraged. However, empirical information on the agroecological differential effects between irrigated and rainfed systems is required. This study adopted National Bureau of Statistics data on Integrated Survey on Agriculture (2018) to estimate these differential effects in rice production systems in Nigeria. Descriptive analysis revealed that the practice of rainfed production still predominate with only about 3% practicing some forms of irrigation. Majority of the irrigated farmers relied on water from rivers/streams (47%) while others sourced from wells and boreholes (17.6%), and lakes/ponds (6%). As a result, only 30% of the rice farmers were able to perform year-round irrigation, which is self-managed (93%) by the resource-poor farmers. Notwithstanding, irrigation was found to have positive and significant effects on output production of rice. Average output per hectare stood at 868.23kg and 463.24kg for irrigated and rainfed systems, respectively. The Cobb-Douglass estimates show the potential of irrigation in combination with production input in returning positive output in rice systems. The study therefore calls for efforts to entrench sustainable local context-base irrigation agro-ecology systems through policy interventions such as training, financing, and input support for rice farming in Nigeria.

Key Words: Agroecology, irrigation, rainfed, rice, output

1. Background

Small scale farmers in Nigeria rely on rainfall and are thus significantly affected by climatic change and weather variabilities. Climate change has been recognized as an important factor in crop production with its attendant threat to yield and agricultural productivity [1,2] Studies of [3,4,5] have demonstrated the vulnerability of Nigeria to the whims of climate change due to its long coastline which prone the country to sea level rise and risk of flood as well as the risk of fierce storm and drought due to its closeness to desert lands in the North,

Several studies have further investigated the impact of climate change risk on agricultural productivity and crop yield [4,6,7] These studies concluded by recommending the need to adopt climate smart agricultural (CSA) practices as panacea for mitigating the effect of climate change on crop yield and agricultural productivity in Nigeria. Some studies have utilized localized data to document several CSA practices in Nigeria as well as their determinants [8,9]) while others such as[10] adopted national data to examine the determinants of CSA adoption among smallholders in the country. Meanwhile, none of these studies adopted the agroecological approach to examining the implication of CSA adoption for productivity of a specific crop. In this study, therefore, emphasis is placed on the differential effects of adoption of CSA practices occasioned by producing rice under two different agro-ecologies (irrigated and rainfed) in Nigeria. This study is thus, motivated on the ground that Nigeria cannot achieve sustainable rice self-sufficiency or export production under a rainfed agricultural practices. As such, empirical evidence that can drive policy attention towards development and promotion of agroecological practices that fit local context is required. This is what the current study seeks to achieve.

Irrigation ecology has been shown as key to increasing rice production, [11]; enhancing commercialization [12, 13] and increasing returns to farmers [14]. An empirical study by [15] has underscored the potentials of irrigation rice production in promoting rice self-sufficiency in Nigeria. The study revealed that the prospect of achieving rice self-sufficiency through irrigation farming is hampered by underdevelopment of the subsector. However, this study, similar to others in Nigeria is limited in its coverage of the effects of irrigation agroecology o productivity on the one hand. On the other hand, the joint effects of irrigation with other production output on production is limited. Against the above backdrop, this study not only seek to provide evidence on the extent and types of practices of irrigation rice farming but also the associated productivity gains occasioned by this agroecological differentials.

Concept of Agroecology

The concept of agroecology started with the American agronomist Basil Basin in 1928 who referred to agroecology then as exclusively the application of methods of ecology to the process of agronomic research. This thinking progresses during 196os to 1980s, influencing the concept of agroecosystem as transforming the ecosystem by humans for exploitation [16] . In the 1990s and 2000s, the coverage of agroecology increased globally such that agroecosystems are now used to understand and define the entire production system, distribution, and consumption of food resources, in all its components (agricultural, agronomic, economic, environmental, and social [17]. Agrosystems thus transcended the farm to encompass the entire food system and the interaction among units.. Agroecology has now become a way of building relationship-based market systems that are equitable, just, and accessible for all [18]. Agroecology is now viewed as a broad system that encompasses research and education, action and change and their interactions towards a food system that is ecologically, socially, and economically sustainable.

Meanwhile, agroecology as used in the context of this study relates to [19], where agroecology was traced to area of crop ecology in which scientists explore where crops were grown and climatic conditions where each was best adapted. In Nigeria, the various rice agroecology includes rainfed upland, rainfed lowland, mangrove swamp, deep water floating and irrigated ecology [15; 20]. Within the irrigated ecology the various irrigation practices as identified by this study include the use of water from rivers/streams, well, boreholes, and lake/ponds.

2. Materials and Methods

2.1 Data Source and Scope

The study examined data from the fourth wave (2018/2019) of the Living standard Measurement Study/ Integrated Survey on Agriculture (LSMS/ISA) of the Panel General Household survey of Nigeria. The umbrella General Household Survey (GHS) is a sample of 22, 000 households from which the GHS Panel was drawn to track activities and outcomes in the Nigerian agricultural system. While, the GHS-cross-section draws mainly from the Living standard Surveys, the GHS panel, focused on agriculture in addition to support from the National Agricultural sample Survey (NASS); covered data on income generating activities, food consumption, household expenditure types of agroecology, production output as well as other factors within the Nigerian agricultural systems. The initializations (in 2010) of the GHS-Panel surveyed 5000, farming households to be involved in a longitudinal data coaction process within the Nigerian agricultural system.

Data need for this study aggregated as: Farm level characterization, Agroecological systems in rice farming and production output were assembled from the merge of the sections within the “Agriculture questionnaire” of the LSMS/ISA.

2.1 Empirical Analysis

The result of this study relied strongly on descriptive exploration, with relevant inferential statistics to assess the power of different agro-ecologies in driving production systems patterns of rice framers in the country.

The data was thereafter analysed with the Cobbs-Douglas production function; in order to generate parameters of factors that drive production output in view of possibilities of the two identified rice farming agro-ecologies (irrigated versus rainfed). The Cobbs-Douglas production function is essentially a non-linear estimation of production output as a function of the inputs used in the production process [21]. The general formulae relate production output as function of capital and labour so that ;

$$Q_i = AL^{\propto}K^{\beta} \quad (1)$$

Where Qi is the output; A is eth efficiency parameter, which is related to improved technologies; and L and K are vectors of labour use and capital use. α *and* β are the parameters of L and “K;” which in a Cobb-Douglas function are the elasticities. In general, however, the Cobb-Douglas function is a relationship between output and the factors of production $(X_1, \dots, X_n)$ in the process, so that with regards to the study, the production function is estimated as:

$$y_i = (L_I, La_i, S_i, F_i, P_i : A) \quad (2)$$

Where :
y_i is the output of rice produced in the year (kg)
L_i is the capital stock, represented by the Are of land cultivated (ha)
La_i is the number of labour used per ha of land cultivated
S_i is the quantity of seed used per ha (kg/ha)
F_i is the quantity of fertiliser used per ha (kg/ha)
P_i is the quantity of pesticides used per ha (kg/ha)
A represents technology, which is a dummy variable (1=Irrigated agro-ecology; 0: non-irrigated/rainfed agroecology).The estimates for A represents the Total Factor productivity not accounted for by other input use.

3. Results and Discussion

3.1 Farm-Level Characteristics

The farm-level characteristics of rice growing households as presented in Table 1 showed that an insignificant proportion (~3%) of the households engaged in irrigated rice production during the production year in focus. Among them, about 47% relied on rivers/streams as source of water while about one-fifth relied on well and boreholes.

Table 1: Distribution of Respondents by Rice Farm Level Characteristics

	Farm Characteristics	Frequency	Percentage
1	Type of rice farming		
	Irrigated	133	2.85
	Rain-fed	4, 533	97.15
2	Source of irrigation		
	Well	23	17.29

	Boreholes	23	17.29
	Lakes/Natural ponds	8	6.02
	Created Ponds	4	3.01
	Rivers/Streams	63	47.37
	Other sources	12	9.02
3	Duration of irrigation		
	Seasonal	93	69.92
	Year Round	40	30.08
4	Management of irrigation		
	Self-Managed	124	93.23
	Farmer Community	8	6.02
	Community	1	0.75

Source: NBS-GHS 2017/2018

As a result, only about a quarter of the households (30%) was able to engage in year-round irrigation and most households' irrigation system is self-managed as indicated by 93%. This will no doubt limit the capacity for expanding area cultivated.

3.2 Farm Input Use by Agroecology

Rice farming required the use of some essential inputs such as fertilizer and labour as inadequate use of such critical input can result to low output. The analysis of the use of inputs by irrigated and rainfed farming households in presented in Table 2. Land size was on the average about 0.5 ha, on the national average. This was similar for rainfed rice farming households. Irrigated farming households had larger farm size of 0.76 ha.

The results indicated the low use of fertilizer and labour. Although the use of fertilizer was relatively higher for irrigated households (1.47kg/ha) compared to rainfed households (11.98kg/ha). Labour use was also estimated at an average of 5 persons/ha for both households. Seedling rate was similar across both rice growing ecologies, averaging 47kg per ha.

Table 2: Average Input Use by Rice Production Agroecology

Farm Input	**Irrigated**	**Non irrigated**	**All**
Farm size (ha)	0.76	0.47	0.47
Pesticides (liters/ha)	17.0	7.69	8.17
Seeds (kg/ha)	46.52	46.70	46.70
Fertilizer	12.47	11.98	11.99
Labour (number)	4.66	5.27	5.25

Source: NBS-GHS 2017/2019

3.3 Output Differentials by Agroecology

The analysis of output differentials between irrigated and rainfed households presented in Table 3 revealed mean output of 868.23kg and 463.24kg, respectively. The differential in value of rice output was significant at 10%, with value of irrigated rice output greater than rainfed output by up to N15, 987.59 in the harvest season.

Table 3: Test of Means of Quantity of Output (kg/ha) Differentials by Agroecology

Production output/System	Irrigated	Rainfed	All	Difference	T Test	Pr>t test
Quantity (kg)	868.23	463.24	474.79	404.99	4.83	0.000
Value (Naira)	78, 189.89	62,202.3	62, 954.36	15, 987.59	1.55	0.07

Source: NBS-GHS 2018/2019

3.4 Agroecology Differentials and Rice Output

The effect of irrigation on rice output was analysed by estimating equation 1 using a dummy variable to capture the effect of irrigation; while separate estimations were also carried out for irrigated and rainfed rice farming households. The result of the various analyses is as presented in Table 4. In the aggregate model, the effect of seed use was positive (0.93) and significant at 1% significant. However, farm size was negative (-0.35) at 1% significance.

The coefficient of irrigation was positive and just significant at 10%. In the disaggregated models, however, only farm size, fertiliser, and labour use were negative and significant, while seed was positive and significant. For rainfed households, farm size was negative (-0.33) while seed use was positive (0.93) and significant at 1%.

Table 4: Effects of Irrigation on Rice Output- Results of Cobb Douglass Production Function

Variables	Aggregate Coefficient (std. err)	t-values	Irrigated Coefficient (std. err)	t-values	Rainfed Coefficient (std. err)	t-values
Farm size	-0.35*** (0.03)	-10.83	-0.64*** (0.10)	-5.90	-0.33*** (0.03)	-9.53
Seed	0.93*** (0.26)	10.55	1.27** (0.59)	2.16	0.93*** (0.09)	10.3
Fertilizer	-0.05 (0.05)	-0.84	-0.41** (0.19)	-2.20	-0.01 (0.05)	-0.24
Labour	0.04 (0.04)	0.97	-0.41* (0.24)	-1.72	0.04 (0.04)	0.96
Irrigation	0.26* (0.14)	1.79	-	-	-	-
Constant	2.71*** (0.37)	7.4	3.00 (2.38)	1.26	2.7*** (0.37)	7.32
F stat	51.96***		11.01***		56.34***	
R^2	0.16		0.42		0.15	
Adjusted R^2	0.16		0.38		0.15	

*, ** and *** significant @10%, 5% and 1%, respectively Values in parenthesis are standard errors

4. Discussion

4.1 Farm-Level Characteristics

The low proportion of irrigated rice farmers in the data suggests a limited level of technological improvement in the rice framing system in Nigeria. This is despite increased attention given to the rice subsector by the federal governed of Nigeria in its many agricultural policy. The opportunity for expansion of farming system is also severely limited by the source of irrigation, which was mainly rivers/stream; and which is subject to seasonality. This may also have accounted for the less than average proportion of all year-round rice framing among the respondents.

4.2 Input use in Rice farming

Farm size distribution reflects the continued smallholding nature The extent of input use in rice agro-ecologies implies resource limitation faming rice farmers in the country. The average input used by the farmers are much lower than the recommended fertiliser, pesticides, and seed use in rice farming. In providing a guide to rice production, [22] specified fertiliser rates of 80-100kg/ha respectively; therefore, suggesting lower input use from the data. Seed rates were however close to the lower range (50kg) of seeding rate for rice farming suggested for Nigerian rice farming. The limited use of these inputs can be attributed to lack of access and high cost of the inputs; with implication for area expansion and output growth. The consequence of this is a lower productive potential than expected for the capital stock available.

4.3 Output differential in rice agro-ecologies

Output level of rice farming households was on the average lower than expected return to rice farming per hectarage in the subregion and globally [22,23]. However, the differentials in output between irrigated and rainfed rice farming households is a confirmation of the significance of irrigation as a panacea for achieving rice self-sufficiency and export production in Nigeria. Output differentials were especially significant in rice farming agro-ecologies, with irrigated farming returning greater output per hectarage on rice production processes above national average on rainfed agroecology.

In terms of value of rice output, there was slightly more monetary returns to irrigated rice farming households than rainfed households. Moreover, it appears that farmers involved in irrigation were also more likely to have better use of other inputs within their farming systems, thereby increasing yield and quality of harvested rice. The differential in value is occasioned by seasonality in price movement and corresponding period of harvest of crops [24]. For rainfed rice farming, harvesting period usually correspond with the main season when farmers usually experience low price due to glut in the market while irrigated output usually correspond with the off season when price is relatively favourable.

4.4 Production function estimates

Aggregate estimates of the production function suggests that an increase in farm size would have negative impact on the production output of rice farming households, possibly a result of low input use within existing farming systems. The non-significance of fertilizer and labour in irrigated rice and labour for rainfed rice is a further indictment of the effect of low use of these critical inputs by both households.

Seed use in general was slightly inelastic, returning 0.93 for a 1-unit increased use of seed. However, seed use exhibited elasticity with respect to irrigated agro-ecology; so that a unit increase in seed use would return more than 1 unit in output. This follows with the study of [25]; where use of improved seeds had significant yield improving potential in Nigerian rice ecologies in Southwest, Nigeria. This suggests that irrigation technology helps to improve the potential of other farm inputs in the production systems of the farming households.

The summation of exponents of the production function sums up to ~0.83 in the aggregate model; implying a decreasing return to scale to rice farming in Nigeria. This suggests that farm size is larger than the resources needed to manage it. Thus, farmers may do better by intensifying production rather than invest inland area expansion in rice production [26] (; supporting the negative effect of land size on output.

In general, irrigation technology had a positive, though inelastic effect on rice output, at a low level of significance. This provides empirical backing to the low proportion of irrigated rice farms within the rice subsector. The aggregate effect of which is low production potential of rice in the country. The implication is grave for achieving the expected export potential and rice self-sufficiency in the country.

5. Conclusion

Nigeria has a huge prospect of achieving rice self-sufficiency and export production if attention is directed at harnessing appropriate irrigated ecology across the country. This study revealed the insignificance proportion of the smallholder farmers that engaged in irrigated rice production in the country and their plight in self-managing their source of irrigated water, a condition that limit their capacity for area and output expansion. The study also underscored the low use of critical inputs like fertilizer and labour and the resultant effects in terms of lower output and yield level compared to national standard. Econometric analysis revealed the irrigation has the potential to increase rice crop yield, especially given the combined use of other critical inputs such as seed

This study concludes by advocating for policy attention directed at promoting the development of irrigation technology that could be self-managed and sustained by farmers resource frontier. Training of farmers on such sustainable irrigation practices will increase the coverage of irrigation in rice growing areas in the country Moreover, low adoption of agricultural inputs will need to be addressed by increasing access and affordability of such inputs, so as to complement the productivity effect of irrigation on rice farms in Nigeria.

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