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Paddy Production Systems and Carbon Footprint: An Economic Profitability Analysis

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ABSTRACT

Kebbi State is one of fifteen states targeted by the Rice Transformation Agenda (ATA) of the Federal Government of Nigeria (FGN) in which rain-fed and irrigated lowland rice production systems were the main priority. This study sets to determine the economic benefit of paddy production systems found in the State. The Ex-Ante Carbon-balance Tool (EX-ACT) was used in estimating the carbon balances of rice production systems while the Cost-Benefit Analysis (CBA) was used in estimating the economic benefit of the systems. The result of the EX-ACT shows that the carbon balances for all production systems were positive. This implies that in all the systems, more carbon is emitted than sequestered hence the values are costs to the society. The irrigation system recorded the highest value of net Greenhouse Gas (GHG) emission. This may be due to the use of fuel-powered irrigation technologies and higher amounts of inputs such as fertilizer. The results of the analyses show that upland and lowland rain-fed systems recorded positive values of net farm income while the irrigation and *fadama* systems had negative values indicating economic inefficiency. The study recommends that the focus should be on increased adoption of improved technologies and production practices for the irrigation and *fadama* systems to reduce environmental effects and to achieve a comparative advantage.

Keywords: Carbon balance, Economic benefit, Efficiency, Greenhouse gas emission, Paddy production systems

INTRODUCTION

Climate change has been viewed as a serious environmental issue that may in the long run threaten the ecology and even economic activity of a country. This is the reason why in 2015 one hundred and ninety-five countries, including Nigeria, came together and agreed to make strides to limit the effects of global warming by reducing

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carbon emissions to a range of 26-28 percent below 2005 levels by 2025. The agriculture and land use sector has been identified as one of the main contributors to anthropogenic greenhouse gas (GHG) emissions. Rice production systems in particular have been shown to contribute to global climate change by emitting carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) to the atmosphere and in turn, are also affected by the changed climatic variables (Ali *et al.*, 2019). Kebbi State is one of fifteen targeted by the Rice Transformation Agenda of the Federal Government of Nigeria in which rain-fed and irrigated lowland rice production systems were the main priority (Federal Ministry of Agriculture and Rural Development (FMARD), 2016). The Government desires to encourage rice intensification and increase supply response through the expansion of irrigation systems. As observed by Brown (1982), the economic profitability of a project is the capacity of the project to maximize the efficient use of a nation's resources in producing national income. For a rice production system to be considered efficient, its assessment must consider the expected impact on the environment such as GHG emissions and its associated Global Warming Potential (GWP) (Boateng *et al.*, 2017). This study, therefore, seeks to determine the economic benefits of rice production systems in the study area. Several studies have been carried out to access the level of profitability and efficiency of agricultural production in Nigeria (Nigerian Institute of Social and Economic Research (NISER), 2001; Liverpool *et al.*, 2009; Mustapha, 2017 and Kassali and Jimoh, 2018), however, most of the literature do not include the effect of paddy production on carbon balance as one of the major externalities in the production systems in estimating their economic benefit.

MATERIALS AND METHODS

Sampling Technique and Data Collection

The study was carried out in Kebbi State, Northwest Nigeria. A multistage sampling technique was adopted in the selection of respondents for the study. The first stage involved the purposive selection of all 13 Local Government Areas (LGAs) identified as major rice-producing areas in the State. The 13 LGAs were grouped into 4 clusters based on the predominant rice production systems. The second stage involved the random selection of two

LGAs from each cluster as representatives of each of the production systems giving a total of eight LGAs. The eight LGAs randomly selected are Yauri and Ngaski (upland rain-fed production system), Birnin Kebbi and Jega (Lowland rain-fed system), Bagudo and Suru (Irrigation system) and Bunza and Argungu, (Fadama production system). The third stage involved the random selection of two villages from each of the LGAs to give a total of 16 villages. The sample frame for small-scale rice farmers in the selected villages was obtained from Kebbi State Rice Farmers Association of Nigeria (RIFAN). The sample size for each of the villages was determined proportionately to the population using Yamane (1967) formula. Primary data was obtained from 375 randomly selected rice farmers for the 2018 cropping season using a combination of structured questionnaire and interview schedule. Data collected included socio-economic characteristics of the farmers, and inputs and outputs of the production systems. The different types of production systems considered are as follows:

Rain-fed Upland System

The upland system accounts for about 30 percent of the total rice area in Nigeria and about 17 percent of total national rice production (United States Agency for International Development (USAID), 2009). In this ecology, the rice crop depends strictly on natural rains for its growth and productivity. Rice yields in the upland ecology are generally low and range from 0.8 to 2 tonnes/ha with a potential of about 3.5tonnes (International Rice Research Institute (IRRI), 1993; USAID, 2009). The rain-fed upland ecology is found in Kebbi State along with about 16 other states in the country.

Rain-fed Lowland System

Rain-fed lowland rice is the most predominant rice production system, accounting for about 47 percent of the total rice-growing area in Nigeria. It is the dominant system found in the floodplains of the rivers Niger, Benue, Katsina Ala, Kaduna, Yobe and their tributaries. Consequently, the rain-fed lowland ecology is found in Kebbi state along with other states in the country such as Adamawa, Akwa Ibom, Bayelsa, Cross River, Delta, Ebonyi, Edo, Ekiti, Lagos, Ondo, and Rivers

States. Increasing use of rain-fed lowlands appears to have been a major source of the rapid increase in paddy production in recent years (Food and Agriculture Organisation (FAO), 2011). It is estimated that this ecology contributes about 53 percent of national rice production (Singh *et al.*, 1997).

Irrigated Rice System

The irrigated rice ecology is the latest rice environment developed in Nigeria (Imolehin, 1991). Sources of water such as rivers, wells and boreholes, supply irrigation water to supplement rainfall for full rice crop growth (Imolehin, 1991). The system is dominated by multiple year cropping seasons as rice cultivation takes place about two times a year (Jamala *et al.*, 2011). This ecology accounts for about 17 percent of the cultivated rice area in the country and contributes about 27 percent of the national rice supply (USAID, 2009). Yields are estimated to range from 2 to 4 tonnes/ha. Nigeria possesses a huge but largely untapped potential for developing irrigated rice. There is an estimated 3.14 million ha of irrigable land, out of which less than 50,000 ha are being used for irrigated rice (Imolehin, 1991). In addition to the irrigation scheme in Kebbi state, Nigeria has irrigation schemes in 16 other states in the country. The establishment of River Basin Development Authorities (RBDAs) in the 1980s gave a boost to rice schemes and irrigated lowland rice production in the country.

Fadama Rice System

Fadama is the Hausa name for irrigable land found in low-lying plains underlined by shallow aquifers. These are found along with Nigeria’s river systems, which are used for small-scale irrigation (Blench and Ingawa, 2004; Ayanwale and Alimi, 2004; Takeshima and Bakare, 2016). Deep water and floating rice represent an increasingly marginalized production system for which area and production figures are generally limited and unreliable (Imolehin, 1991). The floating rice ecology (*fadama*) constitutes 5 percent of the national rice production area (USAID, 2009). The average yield in *fadama* areas is around 1.2 tonnes/ha, with a yield potential of up to 3 tonnes/ha (Singh *et al.*, 1997). The ecology contributes about 3 percent of the national rice output (USAID, 2009).

Cost-Benefit Analysis

The major output of a cost-benefit analysis (CBA) is the benefit-cost ratio (BCR) (Swiss Agency for Development and Cooperation (SDC), 2015). The BCR is a profitability ratio that measures the relationship between the cost and benefit of a farm project or investment. A BCR value that is greater than one implies the project or investment has a positive net present value hence the higher the value of the BCR, the more profitable the project. The BCR is expressed as,

$$BCR = \frac{TR}{TC}$$

Where: BCR = Benefit Cost Ratio, TR = Total Revenue and TC = Total Cost.

Net Farm Income (NFI)

Net farm income (NFI) is the difference between gross income and total costs of production. It is the income generated from the enterprise, which can be drawn without affecting the future rate of production operation. In financial analysis, it measures returns to unpaid factor inputs such as family labour. The NFI is specified as follows,

$$NFI = \sum_{j=1}^{m} P_j Q_j - \sum_{k=1}^{m} P_k Q_k - \sum_{1=1}^{1} FL$$

Where: NFI = Net Farm Income; P_j= price of a unit of jth output; Qj = quantity of jth output; P_k = price of a unit of kth input; Q_k = quantity of kth input; FL = cost of fixed inputs; and $\sum$ = summation sign.

Estimates of Economic Prices

In constructing the economic budgets of the rice production systems, all financial prices were converted to economic prices. To achieve this, adjustments were done for direct transfer payments (taxes and subsidies) and price distortion in foreign exchange. Estimates for the economic cost of rice and fertilizers (urea and NPK 15:15:15) which are regarded as import substitutes were obtained using their Free on Board (FOB) prices. These were converted to the CIF prices in line with International Fund for Agricultural Development (IFAD), (2017). Following Adler (1987), 67 percent part of transport cost was assumed to be tradable. Agrochemicals were assumed to be 50 percent traded (active ingredients which are traded internationally, make about 50 percent of most pesticides) while for all other items that are non-tradable such as farm implements and local seeds, it is assumed that their financial prices reflect their true economic value. Fifty percent subsidy was assumed for improved rice seeds. Rental value instead of market value was used to reflect the opportunity cost of the use of land as proposed by Monke and Pearson (1989). In line with Ogbe *et al.* (2011), the wage rate in the peak-season is the opportunity cost of labour for the period considered. Therefore, the financial cost of labour which was valued during the peak period of rice cultivation was assumed to reflect the true economic cost.

Carbon Balance of Rice Production Systems

The Ex-Ante Carbon-balance Tool (EX-ACT) was used in estimating the carbon balance of the paddy production systems. The EX-ACT is a land-based accounting system, developed by FAO for estimating Carbon stock changes (that is emissions or sinks of CO_2) as well as GHG emissions per unit of land, expressed in equivalent tonnes of CO_2 per hectare and year. In estimating the carbon balance of the production systems using the EX-ACT tool, percentage of total farmers for each of the production systems was used as proxy for the proportion of rice production systems in the State. Total land area for rice production and annual rate of change of land size devoted to rice production were obtained from Kebbi State Ministry of Agriculture (KSMANR) (2017). These data were fed into the tool to have an estimate of GHG emissions per unit of land in each of the systems, expressed in equivalent tonnes of CO_2 per hectare for a 20-year period. To incorporate the GHG emissions per unit of land in each of the systems into the economic analysis, the carbon balance of each of the production systems was valued using the shadow price of carbon as recommended by the World Bank (2017). This was determined by multiplying the annual shadow price of carbon (US\$/tCO_2e) by the annual GHG emissions (tCO_2e). The low and high shadow prices of carbon recommended for the year 2017 were 37 US\$ and 75 US\$/tCO_2eq respectively (Food and Agricultural Organization (FAO), (2017). Accordingly, the low and high values of the shadow price of carbon were used to get varying estimates of the profitability of the production systems. This is consistent with the presence of uncertainty in agricultural production.

RESULTS AND DISCUSSION

The result of the Ex-Ante Carbon Balance Tool as shown in table 1 indicates that the least net emission of 0.02 tCO_2eq is observed by the *fadama* rice system. For lowland rice production system, 0.04 tCO_2eq is the net GHG emission per hectare per year. This is followed by the upland rain-fed rice system with a net GHG emission of 0.05 tCO_2eq. The irrigation system has the highest net emission of 2.39 tCO_2eq. The positive values of the net GHG emission indicate that all production systems add more CO2 equivalent into the atmosphere than it is sequestered. Consequently, the values of the net GHG emission are treated as a cost to the society. As seen in Table1, the high value of net GHG emission from the irrigation system may be a result of farmers employing higher amounts of farm inputs such as fertilizer than the other rice production systems and also the use of fuel-powered generators by farmers in the study area. Table 2 is the estimate for the shadow price of carbon balance for rice production systems in the study areas.

Table 1: Carbon balance of rice production systems expressed in tCO_2eq.

Production Systems	Total Emission	Total emission/ha (20 years)	Total emission/ha/year
Upland Rain-fed	37,465.96	0.97	0.05
Lowland Rain-fed	29,738.30	0.89	0.04
Irrigation	1,980,927.24	48.47	2.42
Fadama	17,473.13	0.46	0.02

Source: Ex-Ante Carbon-balance Tool.

Table 2: Shadow price of carbon balance for rice production systems.

	tCO_2eq emitted per ha per year	Low Estimate ($)	High Estimate ($)
Upland rain-fed	0.05	1.80	3.65
Lowland rain-fed	0.04	1.65	3.35
Irrigation	2.42	89.67	181.77
Fadama	0.02	0.86	1.74

Table 3a: Economic budget of upland rain-fed and lowland rain-fed systems per season.

		Upland rain-fed		**Lowland rain-fed**	
Item	Unit cost ($)	Unit	Economic value ($)	Unit	Economic value ($)
TOTAL OUTPUT (75 kg bag)	20.30	**61**	1238.30	**55**	1116.49
FIXED INPUTS USED/ HECTARE					
Rental Value of Land			50.36		50.22
Handheld hoes	0.60	2	1.20	2	1.20
Sickle	0.22	2	0.44	2	0.44
Cutlass	0.82	2	1.64	2	1.64
Axe	1.20	1	1.20	1	1.20
Knap sack sprayer	3.28	1	3.28	1	3.28
Total Fixed Social Cost			58.12		57.98
VARIABLE INPUTS					
Agro-chemicals					
Insecticides/litre	5.62	2	11.24	2	11.24
Herbicides/litre	4.32	5	21.60	4	17.28
NPK (50 kg bag)	19.73	8	150.97	7	138.11
Urea (50 kg bag)	14.22	5	71.68	4	56.88
Total			**255.49**		**216.23**
Seed /Kg					
Local seed	0.49	36	17.64	49	24.01
Improved seed	2.16	27	58.32	11	23.76
Total seed		**63**	**75.96**	**61**	**47.77**
Bagging	0.37	61	22.57	55	20.35
Transportation cost	0.58		35.20		31.74
Labour cost					
Family labour		31	207.20	39	250.61
Hired labour		72	481.24	59	379.12
Total Labour		**103**	**688.44**	**98**	**629.73**
Sub Total (Social Variable Cost)			**1077.66**		**945.82**
Shadow price of carbon/tCO_2eq/ha					
Low estimate			1.80		1.66
High estimate			3.65		3.35
Total Variable Social Cost with low CO_2 estimate			1079.46		947.48
Total Variable Social Cost with high CO_2 estimate			1081.31		949.17
Average Variable Social Cost with CO_2 estimate			1080.39		948.33
Total Social Cost (average variable cost+ fixed cost)			1138.51		1006.31
Net benefit (low CO_2 estimate)			100.72		111.04
Net benefit (high CO_2 estimate)			98.87		109.35

Average net benefit	99.80	110.20
BCR	1.09	1.11

Source: Field survey conducted for the cropping season in 2018.

Use of Inputs by Rice Farmers

As reported by Takeshima (2016), rice farmers do not seem constrained from using modern inputs despite the reported non availability of subsidised inputs. This is contrary to the general view that African farmers are typically underutilizing modern inputs due to credit constraints or other market imperfections (Morris *et al*. 2007; World Bank, 2007). There is an indication that farmers may be overusing inputs like inorganic fertilizer as indicated in the budget of the irrigated rice system relative to the other systems. As the production systems begin to exhibit diminishing returns to scale due to excessive use of the same plots of land, marginal costs of modern inputs rise, but because rice prices are high, farmers may be inclined to continue using these inputs. Consequently, farmers may realise smaller net revenues as a result of their operating beyond the optimal level of input use that would maximize net revenue. An important implication of this finding is that if farmers are already overusing modern inputs, efforts to stimulate supply response through the promotion of these inputs may be limited. While fertilizer use is still generally low in Nigeria (Liverpool-Tasie and Takeshima, 2013), it was also observed that its use is higher when limited to the rice plots. At the national level, around 75 kilograms of inorganic fertilizer per hectare (kg/ha) and 215 kg/ha are used on rice plots and irrigated rice plots, respectively (Liverpool-Tasie and Takeshima, 2013; Takeshima and Bakare, 2016). These estimates are lower than those used by rice farmers in the study area. The higher use of fertilizer matches with the findings of Takeshima and Bakare (2016) who reported that fertilizer use in rice production is also generally higher in lowland and irrigated areas in Nigeria, even though application rates vary widely across regions and systems. As expected, the intensity of modern input use for rice production in the study area varies widely across the four different rice production systems.

Table 3b: Economic budget of Irrigation and *Fadama* systems per season.

		Irrigation		***Fadama***	
	Unit price	Number	Economic value	Number	Economic value
TOTAL OUTPUT (75 kg bag)	20.30	67	1360.10	49	994.70
FIXED INPUTS/HECTARE					
Rental Value of Land			33.33		49.75
Borehole	9.63	3	28.89		
Submersible Water pump	15.90	1	15.90		
Handheld hoes	0.60	2	1.20	2	1.20
Sickle	0.22	2	0.44	2	0.44
Cutlass	0.82	2	1.64	2	1.64
Axe	1.20	1	1.20	1	1.20
Knap sack sprayer	3.28	1	3.28	1	3.28
Total Fixed Cost			85.88		57.51
VARIABLE INPUTS					
Agro-chemicals					
Insecticides/litre	5.62	4	22.48	2	11.24
Herbicides/litre	4.32	8	34.56	4	17.28
NPK (50 kg bag)	19.73	11	217.03	5	98.65
Urea (50 kg bag)	14.22	6	85.32	7	99.54
Total			359.39		226.71
Seed /Kg					
Local seed	0.49	46	22.54	30	14.70
Improved seed	2.16	32	69.12	31	66.96
Total seed		78	91.66	61	81.66
Bagging	0.37	67	24.79	49	18.13
Transportation cost	0.58		38.66		28.28
Fuel/litre	2.53	52	131.56		0.00
Labour cost					
Family labour		49	298.11	41	287.10
Hired labour		71	431.96	66	462.17
Total Labour		120	730.07	107	749.27
Sub Total (Social Variable Cost)			1376.13		1104.05
Shadow price of carbon					
Low estimate			89.67		0.86
High estimate			181.77		1.74
Total Variable Social Cost with low CO_2 estimate			1465.80		1104.91
Total Variable Social Cost with high CO_2 estimate			1557.90		1105.79
Average Variable Social Cost with CO_2 estimate			1511.85		1105.35
Total Social Cost (average variable cost +fixed cost)			1597.73		1162.86

Net benefit (low CO$_2$ estimate)	-191.58	-167.72
Net benefit (high CO$_2$ estimate)	-283.68	-168.60
Average net benefit	-237.63	-168.16
BCR	0.85	0.86

Source: Field survey conducted for the cropping season in 2018.

Economic Benefit of Rice Production Systems

Tables 3a and 3b are the economic budget of rice production systems in the study area. Two values of net farm income were estimated for each of the production systems. One was estimated using the low value of the shadow price of carbon, while the other was estimated using the high value of the shadow price of carbon as recommended by FAO (2019). The BCR on the other hand was estimated using the average shadow price of carbon, derived by getting an average value between the low and high carbon estimate. The results show that upland and lowland rain-fed systems recorded positive values for the net farm income while values of the BCR were 1.09 and 1.11, respectively. This is an indication of economic profitability hence rice production using the two systems is profitable. The net farm incomes for the irrigation and *fadama* systems on the other hand were negative with BCR values less than one, indicating non profitability of the systems. The net benefit for the upland rain-fed system was \$100.72/ha (using low carbon estimate) and \$98.87/ha (using high carbon estimate).

For the lowland rain-fed system, the net benefit was \$111.04 /ha (using low carbon estimate) and \$109.35/ha (using high carbon estimate). In the case of the irrigation system, a net benefit \$-191.58 was recorded using low carbon estimate while \$-283.68 was recorded using high carbon estimate. The *fadama* system had higher values of \$-167.72 (using low carbon estimate) and \$-168.60 (using high carbon estimate). The results of both analyses indicate that the economic efficiency of the irrigation system is the most affected by the value of GHG emitted into the atmosphere as a result of more CO^2 emission from the use of water pumps, and higher levels of fertilizer.

CONCLUSION

Social profits for upland and lowland production systems were positive indicating that the systems are economically and environmentally efficient. That is farmers in the State are using scarce resources efficiently and therefore have a static comparative advantage in rice production under these systems. The irrigation and *fadama* systems were found to be economically inefficient. This implies the cost of domestic production exceeds the cost of imports consequently, the systems would need government support through distorting policies to survive (usually not advisable in a competitive economy). Therefore, efforts to increase rice production through the expansion of irrigation systems need to be carefully designed bearing in mind the environmental cost to the society so that the negative environmental externalities are minimized. Farmers, especially those producing under the irrigation systems should be targeted in the campaigns for climate-smart agriculture and the use of improved practices that would reduce the effect of conventional agriculture practices on the environment such as adhering to the recommended doses of agro-chemicals, site-specific soil-crop fertilizer use and solar-powered irrigation technologies.

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