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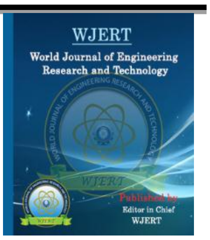

THE IMPACT OF MODERN TECHNOLOGY ON RICE PRODUCTIVITY AND SUSTAINABLE FOOD SECURITY OF BAKALORI DAM IRRIGATION SITES IN ZAMFARA STATE, NIGERIA

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ABSTRACT

In this study the impact of modern technology on rice productivity and sustainable food security of Bakalori dam irrigation area in Zamfara state Nigeria was carried out and analyzed. The Physico-chemical properties and meteorological data of the Bakalori dam were presented which was found to be suitable for the use of some improved rice varieties in the study area. Percentage distribution and mean average of respondent according to the socio – economic characteristics variables were obtained. Hence, it was observed that, out of 105 respondents 64.79% adhere to the average IRV crop spacing of 25-30 cm for optimal yields. Adoption of the modern technology among the farmers are found to be 64.76%. The GPS device is used in mapping the farmland to obtain the accurate farm size, hence the results from GPS accuracy was used to compute mathematically the actual input to be use by farmer for optimal rice yields. Furthermore, the expected crop yields are obtained which were found to be in agreements to the average IRV yields of 5-6 tons per hectare as far as the required inputs are maintained. Finally, the stochastic frontier production function and inefficiency model is used to compute technical efficiency of the farmer production and the results were analyzed.

KEYWORDS; Rice productivity, Irrigation sites, Technical efficiency, Food security, Modern technology.

1. INTRODUCTION

In the future, there will be rice varieties that do not need much water, pesticides, and even fertilizers, a vitamin-enriched rice, a disease or insect-resistant rice that is otherwise difficult to breed by traditional techniques, rice that is 35% more productive than today's high yielding rice, these are all possible with biotechnology. Productivity improving crop technology can be an option for rural farmers to get rid of hunger and food insecurity by increasing production, reducing food price and making food more accessible to the poor (Oko et al, 2012). The use of higher yielding crop varieties facilitates the growth of agro-processing enterprises and non-farm sectors, that stimulates the transition from low productivity subsistence agriculture to a high productivity agro industrial economy (Raju et al., 2015). Embracing the modern technology facilitates developments for rural farmers to get rid of hunger, improve livelihood and food insecurity by increasing production, lower food price, food availability and eradicate poverty. Robert (2014) proposed modern farming technology: impact on farm production and food security in the rice terraces of the Cordillera region, northern Philippines. Their study assessed the impact of modern farming technologies on the productivity and food security in the rice terraces. The study covered four rice terraces clusters located in four provinces in the Cordillera region in the northern central part of the Philippines. Jibril et al. (2017) proposed intelligent irrigation software system in which a global positioning system (GPS) and advanced agricultural information data were employed. Their output described accurate farmland size, crop suitability and the agrochemical requirements. Huge gains in technology since the dawn of the Green Revolution in the 1960s have made substantial impacts on global food supply. Through high yielding varieties and an increase in available inputs such as fertilizer and mechanization, crop yields in developing countries have increased 86% since the Green Revolution, compared with 19.5% to 23.5% lower yield rates had technological change not been adopted. Currently, adoption of biotechnology such as second-generation hybrid or genetically modified crops may have positive effects on yields, farmer income, and contribute to poverty reduction (Emilie, n.d).

In partnership with the University of Port Harcourt in Nigeria, the Alliance for a Green Revolution in Africa (AGRA) has released three lowland rice varieties - UPIA1, UPIA2, and UPIA3 - which are long grains of grade A, high-yielding, and resistant to some economic abiotic stresses such as iron toxicity and drought (AGRA, 2013). Oryza sativa a botanical name of the world's second most popular cereal after maize. Its termed as the most popular crop variety to the average Nigerians, consumed by both the wealthy and the poor. Other rice varieties grown in Nigeria are: Indigenous red grain specie (Oryza glaberrina): Fadama rice, Upland rice, Lowland rice There are numerous varieties of rice that can be cultivated in Nigeria. The process involved in rice cultivation depends on the geographical and ecological factors available. That is to say different varieties thrive in different geographical and ecological zones in Nigeria (AGRO, 2020). Oryza glaberrima, commonly known as African rice, is one of the two domesticated rice species. The spread of these strains is determined by their perceived success, and farmers multiply seed for their own plots when they see a variety doing well in someone else's field, or if a variety is fetching a good price in the market. By comparison to Asian rice, it is hardy, pest-resistant, low-labour, suited to a variety of African conditions. It seems also that strong political factors affect the dissemination of varieties; the most striking example of this is a rice called "China", imported to Nigeria around twenty years ago. It is now largely a subsistence crop (Wikipedia, 2020).

United Nations Development Programme (UNDP) and Food and Agricultural Organisation of the United Nations (FAO) originally identified the Bakolori irrigation project located in Talata Mafara Local Government Area during a soil and water resource survey of the Sokoto Valley in 1969. The actual feasibility was executed by Impresit Bakolori (Nigeria) Limited and its Italian associate, Nuovo Castoro (Oiganji et al., 2015). The contract was initially worth 174 million Naira in 1974 and some 500 million naira in 1982 (400 million U.S. dollars). The contract for the construction of the dam, supply canal and irrigation works was signed in June, 1975 with Impresit Bakolori (Nig.) limited, an indigenous Italian firm, and work commenced the same year. The dam has 450 million cubic metres water storage capacity. The reservoir covers 8,000 hectares and extends some 119km upstream from the dam. By 1979 when the dam was completed, fifteen km-supply canal carries water from the dam down streams of irrigation area where the water is distributed through several hundreds of kilometre secondary and tertiary canals (Yahaya, 2002).

The dam lies between longitude eleven degrees thirteen degrees East and latitude four degree to six degrees North. In terms of climate and vegetation, Zamfara State is within the Sahel Savannah. The rainfall (wet-season) starts between April and June and ends around October when the dry season sets in (Yahaya, 2002). At the Bakalori scheme in the Sokoto Rima

RBDA have 2 cropping seasons per year. The main wet season crops are millet, guinea corn, cowpea, groundnut and cotton. During the dry season, rice, maize, wheat, sweet potatoes, cowpea, groundnut and vegetables are the major crops. Most producers are small to medium scale farmers, and the small-scale farmers often rent land for cultivation. Small farmers produce mainly for home consumption whereas medium to large farmers produce rice for cash. The role of women in rice production is mainly restricted to winnowing. Furthermore, farmers are not organized in unions (Kebbeh et al., 2003).

The experience of farmers in rice cropping ranged between 5 to 25 years for the groups of farmers interviewed. The dry season for rice starts normally in February to March. Soil preparation is mainly conducted with hired tractors. The main crop establishing technique is direct seeding (dry seed) in a row with a stick (drilling). Most Farmers use part of their own production as seed for the following season. The crop is harvested in most cases manually. Most farmers indicated high yields (up to 6.8 t ha^{-1}) after establishment of the scheme and a decline thereafter was 4.9 t ha^{-1} (Kebbeh et al., 2003).

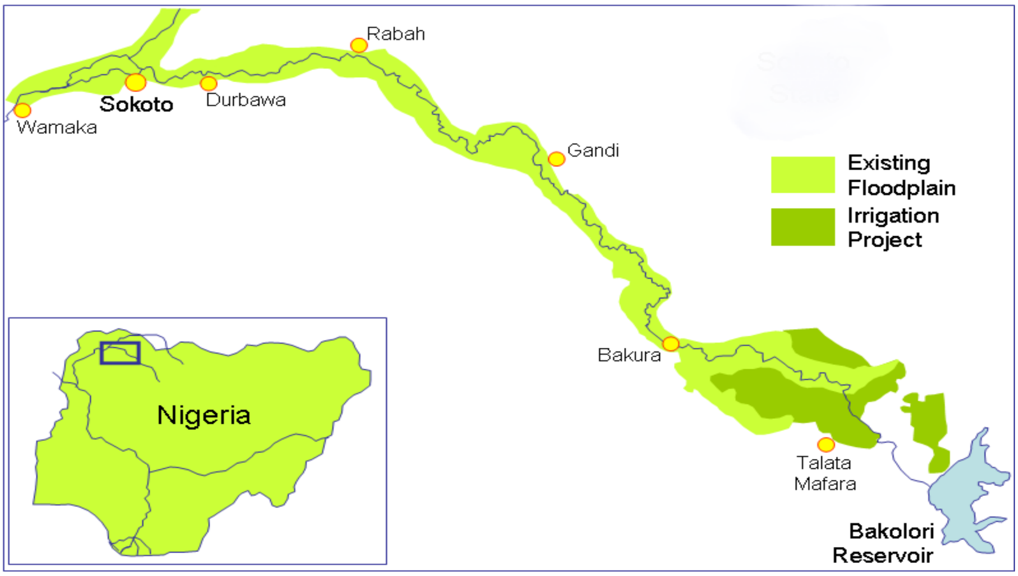

Figure 1: Location of Bakalori Dam irrigation sites, Zamfara state, Nigeria.

Source: (Wikipedia, 2010)

2. DATA COLLECTION AND SAMPLING METHOD

The study adapted a descriptive survey design with 105 respondents to get information pertaining to farm characteristics. The 105 respondents were randomly selected from three local government of the irrigation sites the three local government are Talata-mafara, Bakura and Maradun which were purposively known based on the intensity of their rice production, agro-ecology and accessibility. This was followed by a random sampling of six village consisting of two small clusters or villages called Ward from each local government area. The study further described about the collection of data on modern farming technologies adopted by farmers and their impact on farm productivity and food security. The interview was aided by a semi-structured questionnaire administered on a face to face basis for the field discussions were: general information on the history of irrigated rice production in the site, land tenure, cropping patterns, gender roles, and cooperative organization; the evolution of performance at the scheme and plot levels; land preparation activities and costs; sowing activities and costs; fertilizer, weed and water management; analyses of opportunities and constraints; and general issues.

During discussions, information was generated on the focus and expertise of different institutions; analyses of crop performance, crop spacing, available technologies and important constraints; and the availability of crop management technologies for irrigated rice cultivation. Discussions with policy makers generated information on long-term views. The data used in this study were obtained from a survey conducted in three local government area surrounding the irrigation sites.

2.1 MATHEMATICAL ANALYSIS

i. Stochastic Frontier Production Function and Inefficiency Model

The frontier approaches estimation techniques of relative TE of firms can be generally categorized into two; namely: Data Envelopment Analysis (DEA), a non-parametric mathematical programming approach to frontier estimation; and the stochastic frontiers which involve an econometric estimation. The methods of estimating the relative TE of farmers which is now commonly known as frontier production function began with Farrell's ideas. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data to determine the best practice production frontier (Erhabor, and Ahmadu, 2013). From this, the relative measure of TE for the Individual farmer can be derived. The stochastic production frontier using the Cobb-Douglas function to determine the technical efficiency of the rice farmers is expressed in the log–linear form:

$$\ln Y = b_0 + b_1 \ln X_{1i} + b_2 \ln X_{2i} + b_3 \ln X_{3i} + b_4 \ln X_{4i} + b_5 \ln X_{5i} + b_6 \ln X_{6i} + \left(V_i - U_i\right) \qquad \text{......} (1)$$

Where,

i Stands for the ith farmer

Y = Output of rice (kg)
X_1 = Farm size for rice (ha)
X_2 = Family labour (mandays)
X_3 = Hired labour (mandays)
X_4 = Quantity of rice seed used (kg)
X_5 = Quantity of fertilizer used (kg)
X_6 = Quantity of herbicides used (litres)
V_i = Random (symmetric) error term accounting for deviation of output of rice from the frontier caused by "noise"
U_i = Non-negative (asymmetric) random error term accounting for the technical inefficiency in production.
ln = Natural logarithm
$b_0, b_1, \ldots\ldots\ldots, b_6$ = Unknown parameters to be estimated

The firm specific measure of technical inefficiency is determined from the conditional expectation of U_i given ε_i is mathematically expressed as:

$$E\left(\frac{U_i}{\varepsilon_i}\right) = \frac{\delta_v \delta_u}{\delta_s}\left(\frac{F^*\left(\frac{\varepsilon_i \lambda}{\delta_s}\right)}{1-F^*\left(\frac{\varepsilon_i \lambda}{\delta_s}\right)}\right) - \frac{\varepsilon_i \lambda}{\delta_s}, \qquad i = 1, 2, \ldots., n \qquad (2)$$

Where: F^* is the density function of a standard normal random variable evaluated at, $\frac{\varepsilon_i \lambda}{\delta_s}$, and

$$\varepsilon_i = V_i - U$$

The technical efficiency of the ith farmer is then given as:

$$TE_i = \frac{Y_i}{Y_1^*} = \frac{\exp X_i \beta + (V_i - U_i)}{\exp X_i \beta + V_i} = \exp(-U_i), \qquad 0 \le TE_i \le 1$$

Where,
Y_i = Actual or observed output of the ith farmer
Y_i^* = Frontier output of the ith farmer

The inefficiency parameters of the farmers were estimated using the inefficiency model given as:

$$U_i = a_0 + a_1 z_1 + a_2 z_2 + a_3 z_3 + a_4 z_4 + a_5 z_5 + a_6 z_6 + a_7 z_7 + e_i \qquad (3)$$

Where,

z_1 = Age of farmers (years)

z_2 = Sex of farmers (Male =1, female = 0)

z_3 = Household size

z_4 = Educational level (years)

z_5 = Farmers experience (years)

z_6 = Variety of rice cultivated (improved variety = 1, local variety = 0)

z_7 = Number of improved technologies adopted

e_i = Error term

$a's$ = unknown parameters to be estimated

2.2 Plants need 15 kg of Nitrogen to yield extra ton of grain, which implies 30 kg for two ton of grains. It is assuming that plants take up only half of the fertilizer applied on the field. For optimal yields you need to apply 30 x 2 (60kg) of nitrogen per hectare to produce two extra tons of yields (Adah, 2015).

Farmers in the study sites usually are applying 60kg N/ha, the study compute the quantity of sulphate of ammonia required for x - hectares as follow:

Ammonium sulphate has 21%N as active ingredient. This implies that 21kg of N is contained in 100kg of ammonium sulphate.

Urea has 46%N as active ingredient; this implies that 46 kg of N is contained in 100kg of Urea.

Therefore, 60kg of N = $\frac{100}{21} \times 60 = 285.71kg$ of ammonium sulphate per hectare.

For x ha = $285.714 \times x - hectare$

3. RESULT VIEW

Table 1: Physico-chemical Properties of the Soil at Study Sites.

Parameter In mg/kg	**I/ L 1**	**I/ L 2**	**M/C15km 1**	**M/C15km 2**	**GIS 30 1**	**GIS 30 2**	**Km 12 1**	**Km 12 2**	**JAS 1**	**JAS 2**	**FME Limit**
Temperature (^{0}C)											
PH	27.2	27.3	27.5	27.4	27.2	27.3	27.2	27.4	27.6	27.2	< 40
Conductivity	5.7	5.5	5.6	6.3	5.8	5.7	5.6	5.5	5.6	5.5	6-9
Sulphate	19	6	37	36	22	10	3	8	36	24	1000
Chloride	55.1	20.4	23.5	24.4	94.4	34.1	17.7	14.4	18.4	13.7	500
Phosphorus	5,49	40.8	1,2	1.32	13.13	2.61	11.7	7.3	10.8	6.8	250
Nitrate	0.4	0.6	0.5	0.6	0.5	0.4	0.5	0.4	0.5	0.3	0.1
Cyanide	2.8	3.2	1.0	0.96	4.62	1.57	0.58	0.3	0.5	0.2	20
Chromium	0.11	0.422	0.043	0.048	0.163	0.063	0.038	0.044	0.038	0.027	0.1
Iron	0.048	0.07	0.084	0.096	0.035	0.042	0.07	0.071	0.062	0.041	0.1
Copper	0.183	0.165	0.126	0.151	0.122	0.106	0.192	0.16	0.18	0.142	1,5
Total	0.72	0.28	0.24	0.31	0.18	0.39	0.19	0.35	0.13	0.18	0.1
Nitrogen	0.5	2.1	13.7	14.2	0.9	21.9	9.2	6.1	9.7	6.3	<1
Calcium	12.52	12.31	14.10	13.85	13.77	13.25	13.93	13.42	13.97	13.15	100
Sodium	8.16	8.15	10.18	7.2	9.19	11.19	9.15	10.14	10.17	9.11	200
Potassium	1.3	1.8	1.0	1.3	1.2	1.6	1.7	1.8	1.2	1.5	-
Cadmium	0.051	0.071	0.054	0.068	0.041	0.061	0.113	0.068	0.11	0.69	0.01
THC	1.8	1.9	1.3	1.9	1.7	1.0	1.1	1.8	1.1	1.8	10

1=Soil Sample (0-15cm); 1=Soil Sample (15-30cm); I/L=Irrigation Left; MC=Main Canal 12Km; Km12=12Km along Main Canal; GIS=Pump Station; JAS=Pump Station; FME=Standard of Federal Ministry of Environment, Nigeria

Source: (Oiganji et al., 2015)

Table 2: Meteorological Data for Bakalori Irrigation Sites.

Characteristics	**Description**
Climate	Guinea Savannah agro-ecological zone (Sahel Savannah)
Altitude(m)	341
GPRS Position	$Longitude\ N\ 12.51185^{0}$, $Latitude\ E\ 6.1824^{0}$
Annual rainfall(mm)	500 - 1, 300
Temperature (^{0}C)	27 – 42
Cropping system	Rice-Vegetables-Maize, Rice – follow
Major Farm crop	Rice, Maize, Millet, Sorghum, Beans, Ground nut, Vegetables
Road access	covered the construction of about 200 km road network
Humidity (%)	40 – 80
Soil Nature	Terrace (Sandy loam)

Source: (Oiganji et al., 2015)

Table 3: Recommended Rice Varieties in Nigeria, 1990 – 2013.

IRV name	Cultiva name	Ecology	Days of maturity	Plant height (cm)	Yield range tones/ha	Grain shape	Amylase content	Result to blast	Year of release
FARO44	SIPI 692033	Shallow swamp	110-120	95	4.0-6.0	Long	26.0	R	1992
FARO 45	ITA257	Upland	100	100	2.0-3.0	Medium	17.4	R	1992
FARO 46	ITA150	Upland	105	110	2.0-3.5	Medium	22.5	R	1992
FARO 47	ITA117	Upland	115	105	2.0-4.0	Long	10.5	R	1992
FARO 48	ITA301	Upland	128	100	2.5-4.0	Medium	16.4	R	1992
FARO 49	ITA315	Upland	120	100	2.0-4.5	Medium	16.2	R	1992
FARO 50	ITA230	Shallow swamp	125	100	4.0-6.5	Medium	28.0	R	1992
FARO 51		Shallow swamp	130	100	4.0-6.0	Long		R	1997
UPA1	UPIA		90 -105			long			2013
UPIA2	UPIA		110 – 120			long			2013
UPIA3	UPIA		90 – 100			long			2013
Oryza sativa	IR64					long			
Oryza glaberrina: Fadama rice, Upland rice, Lowland rice									

Table 4: Varieties Cultivated and Average Crop Spacing for Optimal Yields in the Study Sites.

Seed sowed	Spacing applied	Talata – Mafara	Bakura	Maradun	Total	%
Local	15cm – 25cm apart,	2	2	3	7	6.67
Improved	25cm – 30cm apart,	25	23	20	68	64.76
Others	not specify	8	10	12	30	28.57
Total		35	35	35	105	100

Table 5: Application of Fertilizer and use of Pesticides for Optimal Yields in the Study Sites.

Application of fertilizer (NPK, UREA) And pesticides	Talata – Mafara	Bakura	Maradun	Total	%
Yes	27	24	22	73	69.52
No	8	11	13	32	30.48
Total	35	35	35	105	100

Table 6: Showing Survey Sites and IRV Adaption Status.

Local	**Village**	**Sample of Farmers**	
		Adaptor Total	**Non-adaptor**
Talata-Mafara	Service-center, Matusgi	28 35	7
Bakura	Yarkofoji, Birnin-Tudu	25 35	10
Maradun	Gora, Dosara	23 35	12
Grand Total		76 105	29
Percentage(%)		72.38 100	27.62

Table 7: Technical Efficiency of Rice Farmers in the Irrigation Sites.

Technical Efficiency Range (%)	Frequency	Percentage (%)
0.201 – 0.400	2	1.91
0.401 – 0.600	58	55.23
0.601 – 0.800	38	36.19
> 0.800	7	6.67
Total	105	100
Minimum TE	0.263	
Maximum TE	0.887	
Mean TE	0.575	

Table 8: Descriptive Statistics of Socio-economic Characteristics Variables for Improved Rice Varieties of the Study Sites.

Variables	**Description**
Dependent variable	
IRV adoption	1 if the respondent plants IRVs, 0 otherwise
Independent variable:	
Farmer Characteristic	
Sex	1 if the farmer is male, 0 otherwise
Age	Farmer Age in years
Marital Status	1 if the farmer is married, 0 otherwise
Family size	1 if the farmer has family members, 0 otherwise
Educational Level	1 if the farmer has formal education, 0 otherwise
Farming years of experience	1 if the farmer has years of experience, 0 otherwise
Family labor	Active family members (between 15– 65 years)
Hired labor	1 if the farmer hired labor, 0 otherwise
Occupation	1 if the farmer employment is farming, 0 otherwise
Farm Characteristic	
Farm size	Cultivated land area in the current year (hm2)
Land type	1 if household own low land, 0 otherwise
Institutional access related variable	
Access to credit	1 if the farmer has access to credit, 0 otherwise
Used of improved seed variety	1 if the farmer used listed items accordingly, 0 otherwise
Seed Kg/ha	
Urea Kg/ha	
NPK Kg/ha	
Herbicide 1/ha	
Constant	
Technology specific variable	
Extension service	1 if the farmer received visits in the previous years, 0 otherwise
Seed access	1 if seed is available at local store, 0 otherwise
Seed cost	1if IRVs are expensive than the old one, 0 otherwise
Distance to market	1 if the farmer has access to market at ease, 0 otherwise
Off-farm work	1 if participate in off-farm work, 0 otherwise
Technology specific variable	
Yield potential	1 if the IRVs to yield more than the old one, 0 otherwise
Pest resistance	1 if the IRVs to be more resistant to field pests than the old one, 0 otherwise
Palatability	1 if the IRVs perceived to be more palatable than the old one, 0 otherwise
Acceptability	1 if it is easier to sell grain from IRVs compared with the old one, 0 otherwise

Table 9: Sample of respondent Farmland Analysis and required agrochemical inputs.

Farm Land Elevation							Farm size	Agrochemicals input				output
land	**Elava-tion1**	**Elava-tion2**	**Long1**	**Long2**	**Latitude1**	**Latitude2**	**Hectare**	**NPK (Kg)**	**UREA (Kg)**	**Seed (Kg)**	**Herbicide (liters)**	**Yields (tons)**
1	364	366	12.38250	12.38340	005.58664	005.58694	1.18	168. 57	76.96	110.92	2.92	5.310
2	398	397	12.38161	12.38139	005.58315	005.58343	1.77	252.86	115.43	166.38	4.37	7.965
3	292	297	12.38219	12.38214	00558008	005.58115	1.37	195.71	89.35	128.78	3.38	6.165
4	298	299	12.38109	12.38017	005.58417	005.58388	1.09	155.71	71.09	102.46	2.69	4.905
5	299	299	12.38185	12.38190	005.58237	005.58210	1.90	271.43	123.91	178.6	4.69	8.550

Table 10: Percentage Distribution of Respondents according to Socio-economic Characteristics Variables.

Variables	Frequency	Percentage (n=105)	Mean (M)	σ
Sex				
Male	98	93.33	52.5	45.50
Female	7	6.67		
Marital status				
Single	25	23.81	35.0	29.44
Married	75	71.43		
Other	5	4.76		
Age				
≤ 30	13	12.38	21.0	14.26
31 – 40	27	25.71		
41 – 50	45	42.88		
51 – 60	17	16.19		
Above	3	2.86		
Household size				
≤5 persons	25	23.80	35.0	9.63
6 – 10	48	45.71		
Above 10	32	30.48		
Occupation				
Full time farmer	55	52.38	21.0	17.25
Trading	13	12.38		
Pension	7	6.67		
Civil servant	15	14.28		
Artisan	15	14.28		
Mode of land acquisition				
Rent	65	61.91	21.0	22.30
Gift	8	7.62		
Borrowed	5	4.76		
Inheritance	16	15.24		
Purchase	11	10.48		
Years of farming experience (years)				
1-10	65	61.91	21.0	22.85
11-20	21	20.00		
21-30	9	8.57		
31-40	8	7.62		
41-50	2	1.91		
Farm size				
<1 ha	88	83.81	26.3	35.86
1-5 ha	12	11.43		
6-10 ha	3	2.86		
Above 10ha	2	1.91		
Farm size devoted to IRV rice variety				
<1 ha	68	64.76		
<5 ha	25	23.81		

5-10 ha	7	6.67	26.3	25.33
Above 10ha	5	4.76		
Type of rice varieties grew by farmers				
FARO-44	65	61.91		
Jamila	10	9.52		
Jef	7	6.67	15.0	20.46
Yar Thailand	8	7.62		
Jiranni zawara	7	6.67		
Yar-tunga	5	4.76		
CP	3	2.86		

3.1 DISCUSSIONS OF FINDINGS

Table 1 indicated how the cultural practices and farming activities carried out in the irrigation sites has altered the physico – chemical properties of the soil as a result of both appropriate and inappropriate application of organic and inorganic fertilizer to the soil. The soil sample taken for analysis shows that pH of the soil ranged between 5.5 – 6.3. The lowest pH of 5.5 was found at irrigation left farmland about 12km of main canal and the maximum pH of 6.3 was found in subsoil (15 – 30cm) of farmland at main canal. It was observed that the electric conductivity varied from 3 $3-80\mu S/cm$ and assumed to be within the acceptable limit. The sulphate concentration, chloride, nitrate, cyanide, phosphorus, potassium, chromium, iron calcium, sodium and total hydrocarbons present were within the acceptable limit. Furthermore, the level of cadmium, copper, and total nitrogen were found to be above the acceptable limit in all the locations, which could be attributed to the use of agrochemicals and use of pesticides in the farms depending on their solubility in water, thus the level of phosphorus and potassium was found to be beyond the acceptable limit (Oiganji et al., 2015).

Table 2 Bakolori reservoir is situated at Longitude 12.51185N and Latitude 6.1824E. It was located in Zamfara State, and was completed in 1978. It has a capacity of 450 million cubic meters, with a reservoir covering 8,000 hectares extending 19 km (12 mi) upstream (Ibrahim, and Ogueji, 2017). The climate of the study site was of Guinea savanna (sahel savanna). The mean annual rainfall of the area ranged from 500mm – 1300mm. the relative humidity ranging from 40% to 80%. The area experiences the highest temperatures between March and May ranging between 27 – 42 degree.

Table 3 shows thirteen (13) varieties recommended between 1990 – 2013, they made up of upland rice, lowland and deep water ecology rice with high-yield, blast – resistant varieties. Moreso, in order to achieve the objective of people's demand on rice, fifty-one rice varieties have been bred from 1990-2000 to suit the various ecological zones of the country rainfed uplands, flooded plains and irrigated plains. These varieties have properties that satisfy different consumer preferences in terms of grain type, swelling capacity, amylase content, protein and cooking time. The study indicates that farmers in the different States have higher preference for FARO 44 and FARO 46, respectively. Therefore, the adoption of FARO 44 by different States in Nigeria is expected to be high compared to other rice varieties (Udemeze, n.d).

Table 4 indicated that out of 105 respondents 64.75% adhered to required crop spacing needed for optimal results of the improved varieties. Those for local varieties applied spacing of 15cm – 25cm accounts for 6.67% and the remaining 28.57% accounts for spacing unspecified and were for other varieties. This indicated that application of optimum spacing within and between rows of crops results in optimum yields in crop production. It also, encourages formation of foliage canopy which helps in suppressing weeds emergence. Too close spacing therefore affects optimum yield of the crop (Adah et al., 2015).

Data entries in Table 5 show that majority 69.52% of the respondents adopted fertilizer (NPK 20:10:10; and urea) for their irrigated rice. Similarly, 30.48% of the respondents were at the awareness, interest, evaluation and trial stages. Since majority 69.52% of the respondents have access to fertilizers, this could increase their propensity to adopt the technology. This result indicated that lack of access to availability and timeliness of fertilizer delivery discourage adoption.

Table 6 shows that 72.38% of the respondents from the survey sites adopt the modern technologies, while the remaining 27.62% were not able to meet up as a results of certain constraints in the farming process. This indicated that when a new farming practice is introduced in a community, not all people adopt at the same time, some farmers no matter what will continue their farming based entirely upon traditional agriculture. Once innovation had been introduced, the central objective is to encourage farmers to adopt.

Table 7 shows the technical efficiency of small-scale rice farmers in Bakalori area. It focused specifically on the socio-economic characteristics of the rice farmers, production function for rice, level of technical efficiency of the farmers and their inefficiency parameters. Data used for the study were obtained using a structured questionnaire. A total of 105 respondents from the three local government provided useful data for analysis. Data analysis was done using descriptive statistics, stochastic frontier production function and inefficiency model as shown in the Table, the level of TE of the rice farmers ranged from 0.38 - 0.99 with 55% of the farmers falling within the range of 0.401 - 0.600. The average TE was about 0.58. This indicates that there was still ample opportunity (45%) for the rice farmers to increase their TE in rice production. Higher levels of average TE for farmers were, also reported by Erhabor and Ahmadu (2013).

Table 8 gives descriptive information of socio-economic characteristics about the farmers' adaptation of the improved rice varieties in the study sites, data generated from the field discussions found that small-scale farmers rely primarily on family labor for most field activities, using hired labor to meet shortfalls in the availability of family labor. The cost difference here is attributed mainly to high land rental fees incurred by small-scale farmers. The important budget items for small farmers at the site are land, harvesting, weeding and fertilizer costs.

Input Costs and Access to Farm Credit: A significant proportion of farmers engaged in irrigated rice production are considered resource poor and have limited access to credit for input purchases. High cost of inputs and lack of credit were identified as primary constraints across all farmers' categories. Large, medium and small farmers in all sites indicated that fertilizers and herbicides were too expensive, and that formal credit for the purchase of inputs was largely unavailable. A functional and decentralized credit mechanism would enable producers to make the required investments to improve productivity at the plot and scheme levels

Farmer's management practices: Gaps between potential yield and average yields achieved by farmers are partly due to the limited use of inputs (e.g. fertilizers, agro-chemicals), but a considerable part of the gap is caused by sub-optimal management practices. show that the use of improved input management strategies could significantly increase irrigated rice yields and revenues.

Access to Improved Varieties and Good Planting Material: Access to improved varieties and good quality seed was cited as a principal constraint during the surveys. the emphasis was on short duration and high yielding varieties. Farmers and extension personnel in these zones indicated a preference for varieties that perform well in these agro-ecologies. Availability of good quality seed was also identified as an important constraint. All farmers in the study indicated using seed from their previous harvests or purchasing seed from local markets.

Machinery for Harvest and Post-Harvest Operations: Farmers overwhelmingly rely on manual labor for crop harvest, and labor shortages and extensive crop losses are common. The unavailability of appropriate harvest and post-harvest equipment is a major constraint across the study areas. Manual harvesting is labor intensive, expensive and associated with crop losses due to late harvesting that result from chronic labor shortages. Machines are generally insufficient, not available on time and unsuitable for use in heavy soils that may be wet during harvest period. There is also the report of frequent breakdowns and the unavailability of spare parts for the maintenance of machines. Cost-effective, Small threshing equipment and efficient small machinery for harvest and post-harvest operations could have significant impact on irrigated rice production in the Bakalori area.

Pests and Diseases: Insect and bird damage were identified as the pest problems in the study areas. Birds specifically mentioned were identified as the key problems in different sites in the Bakalori irrigation sites. Whereas, no clear control measures were suggested or observed for the problems in the different sites and it attribute potential crop losses of about 10 to 100 %.

Marketing: Access to markets did not emerge as a major constraint in any of the study sites. In all areas, farmers indicated they could readily sell paddy or milled rice after harvest. Discussions with other stakeholders in the sector supported the responses of farmers on this issue. The readily available market for locally produced rice offers significant opportunities for the rice production sector in the area of the study. There are indeed opportunities for rice to become a major cash crop in the area, and this possibility gives additional incentives for investment in the sector. However, most farmers reported receiving relatively low prices resulting from excess supply immediately after harvest.

Research and Extension Support: Research-extension-farmer linkages are extremely weak in all sites covered in this study. Producers in all study sites rely heavily on Rima basin development authorities and state or federal officers for research and extension support. Access to information on improved technologies and crop management strategies is critical to improving productivity in the irrigated rice sector. These services are woefully inadequate in almost all sites visited. The extension staff are more involved in scheme management than providing needed services to rice producers. Furthermore, most extension personnel are poorly trained and lack necessary training materials.

Data in Table 9 show that five farmlands were captured in which all are above I hectare. The goal of farmland mapping is to enable better performance in terms of crop yields, with these new technologies a farmer can make adequate plan for the farming system and encourage farmers to plan well ahead. This result indicated the actual agrochemicals (seeds, NPK, UREA, herbicides) inputs required from the sample of farmlands selected and mapped because the actual size of each farmland was computed. This has helped to eliminate the issue of low input or over applying inputs. The projection of the crop yields can easily be captured if the proposed inputs were properly addressed.

Table 10 reveals that about 93.33% of the respondents are male while 6.67% are females. Meaning that the gender distribution of the rice farmers in the area skewed towards male respondents which was agreed with other researchers’ findings. the results show that 71.43% were married, while 23.81% were single and the remaining occupied 4.76%. the results indicated that married people accounts for majority of rice farmer’s population in the area. Data of the respondents show that 12.38% of the respondents were within the range of below 30 years of age, while 25.71% were within the range of 31 – 40 years, those within the range of 41 – 50 years were 42.88%, the range within 51 – 60 years were 16.19%, those farmers above 60 years’ accounts for 2.86%. The results indicated that young people were the majority of economic active class. Entries show that 23.80% constitutes the population of household less than 5 persons, those within the range 6 – 10 households constitutes of 45. 71%, sizes above 10 persons constituted 30.48%. this indicated that the farmers relatively had large family sized that enable them to engage in family labor for them to reduce the cost of hiring labor. The greater proportion 52.38% of the respondents were full time rice farmers, artisan and civil servants constituted of 14.28% each, 12.28% had trading as the major occupation, those relied on pension accounts for 6.67% of the populations. This indicated that the rice farmers in the area have rice farming as their major occupation. From the table, land rent constituted of 61.91%, followed by 7.62% as a gift, 4.76% were borrowed, 15.24% of the respondents inherited the land, while the remaining 10.48% acquired through purchased. Data show that 61.91% of the respondents had 1 – 10 years of rice farming experience constituted of the majority of respondents’ population, while the least year of farming experience ranged 41 – 50 years’ accounts for 1.91%. The mean years of farming experience was 21 years. This implies that farmers had long period of farming experience. This could increase their knowledge, experience and subsequent adoption of improved new rice varieties and technologies. Data shows that 83.81% of the respondents cultivated less than 1 ha, those of the respondents cultivated less than 5 ha accounts for 11.43%, 6.67% of the respondents cultivated 5 – 10 ha. About 4.76 % of respondents cultivated above 10 hectares of land. The average farm size was 2.5 ha. This implies that all the rice farmers in the area were small-scale farmers and assumed to be predominating in the irrigation sites. Entries in the Table indicate, that 64.76 % of the respondents devoted less than 1 hectare of land to IRV, while 23.81% of the respondents devoted less than 5 hectares of land to IRV. Also, 6.67% devoted 5 – 10 hectares of land, while 4.76% of the respondents devoted 10 hectares and above, respectively. The average farm size devoted to IRV cultivation was 2 ha. This implies that the total, land devoted for IRV production in the area was still under small-scale farming. Entries in Table 9 reveals types of rice varieties grown by farmers in Bakalori irrigation sites, 61.91% of the respondents grew *FARO-44* rice variety, 9.52 % of the farmers also grew *Jamila* rice variety. Similarly, 6.67% of the farmers grew *Jef* rice variety, while 7.62% of the respondents grew *Yar-Thailand* rice variety, 6.67% of the farmers grew *Jiranni-Zawara* rice variety, while 4.76% of the respondents grew *Yar-Tunga* rice variety, while 2.86% of the respondents grew *CP* rice variety. The fact that all 61.91% of the respondents adopted *FARO-44* rice variety among other varieties may be attributed to its unique qualities such as early maturity (110 – 120 days), higher yield, tolerant to some stress, resistant to diseases as well as its low glycemic indices when compared to other varieties.

4. CONCLUSION

The results discussed highlight the constraints, covering a wide array of issues, include agro-economic, biophysical and agro-ecological factors that must be addressed in order to improve the productivity of irrigated rice systems in the different sites of Bakalori dam. Based on these the respondents strongly linked the general decline in irrigated rice yields to the inconsistent policies, poor soil fertility and inadequate support that resulted in significant yield declines on farmers’ fields. Most of the respondents indicated significant decreases in input levels following the poor implementation of subsidies for fertilizer and herbicides. The results also show extremely high yield gaps between farmers in all categories, suggesting high yield variability among producers. Small and medium scale farmers at the Bakalori sites reported mean yields of 5.25 and 4.73 tons per hectare respectively, with individual plot yields ranging from 3.8 – 6.8 and 4.5 to 5.0 tons per hectare respectively.

This observation has important implications for increasing irrigated rice productivity and production in the area. The modern farming technologies adopted by farmers includes: use of high yielding rice varieties, use of fertilizers and pesticides and use of hand tractors replacing human and animal labor and also, there is wide diversity of land and resource endowment, ranging from small farmers with access to less than one hectare of irrigated rice land to large-scale producers cultivating more than one hectares. There is a strong relationship between extent of water control and levels of investment in external inputs like fertilizers and herbicides. In general, the significant production gains can be achieved by better utilization of existing infrastructure. Although farm level decision-making continues to be dominated by men, female farmers continue to play important roles in the irrigated rice area. Women are actively involved in various production and post-harvest operations.

4.1 Recommendations

Based on the findings of the study and the implications, the following recommendations are therefore made:

i. The rice-growing communities in Talata mafara, Bakura and Maradun local government in Zamfara States shall be encouraged and be supported by training and all agric-inputs on credit in order to improve their own paddy yields and revenues with assured buy back system. Government should subsidize the costs of the inputs and make them available in sufficient quantities to the rice farmers through designated government organizations and ministries and Research Institutes only and on early time. Sales of the subsidized inputs in the public markets should be controlled to prevent the hijacking of the inputs by wealthy individuals who will in turn sell them to the farmers at exorbitant cost, thus, constraining the farmers from buying sufficient quantities.

ii. Since there was low access to credit facility by the farmers, government and financial Institutions should make agricultural credit more accessible to farmers. Stringent measures and bureaucratic procedures for accessing agricultural credit should be minimized. Rice farmers on their part should form co-operative societies and/or join Rice Farmers Association of Nigeria to ease their accessibility to farm inputs, especially agricultural credit. Low access of farmers to improve rice varieties developed through research efforts could be minimized by strengthening and refocusing the extension services in the country.

iii. Since young farmers were more technically efficient than older ones, government Should create enabling environment to make farming attractive to the youth. This will settle them down to concentrate on farming. Effort should be intensified in the provision of adult education to aged and uneducated farmers. This could be achieved by the establishment of adult literacy schools in all the rural areas and revitalizing any existing ones.

iv. Results from Table 1 reveals poor soil fertility detection in the study area and it is becoming an impediment to the adoption of improved technology in the area. Thus, farmers reported that poor soil fertility has grossly exposed them to production failure as well as high production cost. Therefore, farmers should gear efforts towards using alternative means like organic farming to boost the soil. And also, extension agent should educate farmers into proper use of herbicides in order to reduce weeds infestation in their farm through self-help effort.

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