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ANALYSIS OF TECHNICAL AND SCALE EFFICIENCY OF IRRIGATED TOMATO PRODUCTION UNDER KANO RIVER IRRIGATION PROJECT, PHASE I

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ABSTRACT
This study examined the technical and scale efficiencies of irrigated tomato under Kano river irrigation project (KRIP) phase I. Primary data were collected from 213 irrigated tomato farmers, using multi-stage sampling techniques in three local government areas covered by KRIP. Data collected was based on the 2014/2015 irrigation farming season using structured questionnaire and were analysed using two-stage Data Envelopment Analysis (DEA). The study established that given the current level of output, small scale farms can produce output using less inputs at 30% and 34% on average. However, 21% of the 152 small scale farms are fully efficient under the variable return to scale while only 17% farms are fully efficient under constant return to scale, indicating that many over 80% of the small scale farms did not operate at an efficient scale, hence adjusting the scale of operation could improve the efficiency. Also, majority (92%) of the medium scale farms category were found operating in the region of increasing returns or the sub-optimal region. This is closely followed by 76% of large scale farm category. This indicates that medium and large scale farms are operating scale inefficiency or below optimum production scale. To achieve the optimum production scale, these farms could do so by decreasing the costs. It was therefore recommended that since the farms were operating below optimum production scale or scale inefficient, farmer-education should be encouraged by extension agents through effective and efficient dissemination of information.

Keywords: Tomato, Irrigation, Technical Efficiency, Scale Efficiency

INTRODUCTION
Tomato (*Lycopersicon esculentum* Mill) is a vegetable crop which is widely cultivated in many parts of the world including Nigeria as an edible fruits and also as an important source of vitamins and cash crop for small, medium and large scales farms (Shankara *et al.*, 2005). The fruit is an essential component of the diet of man and also an important industrial commodity (Jaliya *et al.*, 2007).Despite, the enormous important of tomato fruit in Nigeria, small and medium scales, the majority are engaged in subsistence tomato production. Produce the majority of aggregate output via rudimentary farming systems (Oviasogie, 2005; Ajibolade, 2005). These scales of producers are the driving force of industrial development in both developed and developing countries, therefore, the attentions of governments all over the world have focused on funding and supporting small and medium scale enterprise activities (Adamu, 2005). As part of government efforts to improve efficiency of tomato production and in addition to reducing the uncertainty in yields of rain-fed tomato production due to climatic variability, large scale tomato production has been taken up along the Kano River Irrigation Project (KRIP), Phase I (Olanrewaju and Swarup, 1983; Kano State Government, 2012).The bulk of tomato production lies in the Northern part of the country especially areas around Jigawa and Kano States (Abba and Shehu, 2007). Under the KRIP, a 1500 tonnes per day tomato processing plant is being constructed in the area with the establishment of a specialised market at Kwanar Gafan in Garun Malam Local Government Area. These has provided employment to thousands of the tomato merchants and brokers in local processing and marketing of the commodity (HJRBDA, 2013).

Irrigated tomato production has played a major role in expanding the level of food production leading to the attainment of food self-sufficiency and the overall agricultural development in many developing countries (Ibabu, Nwas and Traxer, 1996; Ojo and Adebayo, 2012). It has also contributed to general improvement in efficiency and productivity of tomato enabling the farmers to generate substantial income and to be gainfully employed all year round (Frederick, 1992; Sekumade and Toluwase, 2014). However, high cost of inputs including fertilizers and herbicides negatively affects the efficiency levels of different scale of tomato producers especially the small scale producers (Adeyemo, Oke and Akinola, 2010). Another major issue limiting tomato production in Nigeria includes low yields due to the use of rudimentary technology inputs, poor yielding seeds/seedlings and lack of or poor adoption of improved production technologies, poor infrastructure, poor access to finance and poor marketing structures. Thus, to improve the efficiency and stimulate the sector, these issues need to be mitigated through adequate research and provision of irrigation technologies which would lead to competitive production Central Bank of Nigeria (CBN, 2010). Consequently, this study examined the technical and scale efficiency of irrigated tomato production under Kano river irrigation project, Phase I.

METHODOLOGY
The Study was conducted in Kano State, Nigeria. The State lies between Latitudes 12^0 37' North to 9^0 33'South and Longitudes 9^0 29' to 7^0 43'West and shares boundary with Jigawa State to the Northeast, Katsina State to the Northwest and Kaduna State to the South. The State consists of two agro-ecological zones namely, Northern Guinea Savannah (NGS) and the Sudan Savannah (SS). The Southern part of the State is in the NGS, which has an annual rainfall of 600-1,200mm while the Central and Northern parts are in the SS, with an annual rainfall of 300-600mm (Kano State Government,

2012). Based on the annual growth rate of 3.0%, the State has a projected population of 13,745,862.84 in 2018 National Population Census (NPC, 2006). Agriculture is the major employer of labour in the state with many citizens involved in farming, animal husbandry and fishery (Muhammad and Atte, 2006; Kano State Government, 2012). The upland crops commonly grown are millets, sorghum, cowpea and maize, while the low land/Fadama crops grown in the state includes tomato, onion, and pepper with rice and wheat grown in the flood plains and irrigated areas. The Research was specifically conducted under Kano River Irrigation Project (KRIP), Phase I because of large scale cultivation and highest number of tomato farmers in the state.

The KRIP is one of the largest and successful projects, not only in Nigeria, but in West African sub-region. It is unique in its design in that the entire water distribution network operates on gravity. Water is conveyed from Tiga Dam to the project site through 18km long main canal, which splits into East (Bunkure) and West (Garun Mallam and Kura) Branches. Crops cultivated include tomato, wheat, onion, maize, rice, garlic, cucumber, potatoes, millet, guinea corn and melon Hadejia Jama'are River Basin Development Authority (HJRBDA, 2013). The KRIP Phase I is currently providing all year round direct employment to about 41,250 farmers and their families. Over 5.0 million man days of employment are being generated as indirect employment to communities within and outside the project area annually. Farmers produce an average of 200,000 metric tonnes of food and cash crops valued at over ₦2.7 billion annually, thereby contributing significantly toward enhancing national food security (HJRBDA, 2013).

Sampling Procedure and Sample Size

Kano state comprises of three agricultural zones, namely Danbatta, Rano and Gaya zones. Rano zone was purposively selected because of its highest number of irrigated tomato farmers. The major irrigated tomato producing local government areas in the zone are Bunkure, Garun-Mallam and Kura which are covered by (KRIP) Phase I, (HJRBDA, 2013).Two villages with high number of different scale irrigated tomato producers were randomly selected from each of the three local government areas. Finally, 10% of the total population (2125) were randomly selected making a sample size of 213. Population of the three categories of scale are homogeneous having similar characteristics in terms of age, location or employment, this form the basis for selecting 10% (Nielsen, 1998; Procter and Meullenet, 1998; Lucas, 2012). This study adopted the categorisations of Haruna (2004) and Bakari (2013) and is given as:

i. all farmers with farm size of less than a hectare are small scale farmers(<1.0ha)

ii.all farmers with one hectare to less than three hectares are medium scale farmers(1.0ha to 2.9ha)

iii. all farmers with three hectares and above are large scale farmers (3.0ha and above)

DATA COLLECTION

Primary data were used for this study. The data collected were based on 2014/2015 irrigation farming season with the aid of structured questionnaire through the assistant of field enumerators under the supervision of the researcher.

Analytical techniques

A two-stage Data Envelopment Analysis (DEA) was used. The technical efficiency was determined using the non-parametric DEA. It is a mathematical programming approach for the development of production frontiers and the measurement of efficiency relative to the development frontiers (Charnes, Cooper and Rhodes, 1978; Rayeni, Vardanyan and Saljooghi, 2010). It is useful in handling multiple inputs as well as multiple outputs and it is considered as deterministic function of the observed variables, and no specific functional form is required. Other main advantages of using DEA are that it performs well with only small number of observations and it does not require any assumption to be made about the distribution of inefficiency. Avkiran (1999) stated that DEA allows the researchers to choose any kind of input and output, regardless of different measurement units (Sufian, 2007; Rayeni, Vardanyan and Saljooghi, 2010). On the other hand, the short-comings of DEA are that it assumes data to be free of measurement error and is sensitive to outliers. The original formulation of the DEA model introduced by Charnes *et al*., (1978) denoted Charnes, Cooper and Rhodes (CCR). The ratio of outputs to inputs is used to measure the relative efficiency of the DMUj = DMUO to be evaluated relative to the rations of all the j = 1, 2. . . n DMU. This basic DEA model implied the assumption of Constant Returns to Scale (CRS). Using Charnes-Cooper transformation and dual formulation under CRS, then

$\theta^* = \text{Minimum } \theta$

Subject to

$$\sum_{j}^{n} = i\,\lambda j\, Xij - \theta io \leq 0 \qquad i = 1, \dots, m$$

$$\sum_{j}^{n} = i \qquad \lambda j\, y_{rj} - Y_{jo} \geq 0 \qquad r = 1, \dots, s$$

$$\lambda j \geq 0 Aj$$

The optimal solution, θ*, yields an efficiency scores for a certain DMU. The process is repeated for each DMU. DMUs for which θ*< 1 are inefficient, while DMUs for which θ*= 1 are boundary points or efficient.

RESULTS AND DISCUSSION

Estimate of Technical Efficiency Based on the Three Sizes of Production in the Study Area

Employing the output-oriented DEA under Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) models, technical efficiency and scale efficiency for the three sizes of irrigated tomato farms were estimated. The summary statistics for technical efficiency in terms of constant returns to scale, variable returns to scale and scale efficiency are presented in Table 1 for the three sizes of irrigated tomato farms. It was found that the estimated mean technical efficiency measure for small scale farms are 70% and 66% in terms of variable returns to scale and constant returns to scale, respectively. This implies that inefficiency in the use of inputs exist, which means that the current level of output can be produced using less inputs at 30% and 34% on average. Furthermore, 21% of the 152 small scale farms are fully efficient under the variable return to scale while only 17% farms are fully efficient under constant return to scale, indicating that many over 80% of the small scale farms did not operate at an efficient scale, hence adjusting the scale of operation could improve the efficiency. Similarly, the estimated mean technical efficiency measure for the medium scale farms were 83% and 33% for variable returns to scale and constant returns to scale, respectively. This implies that this scale of farms maintains some level of efficiency in the use of inputs which means that the current level of output can be produced using only 17% of less inputs on the average. It was found that 73% and 14% of the 36 medium scale farms

were fully efficient, this indicated that over 50% of the medium scale farms did not operate at an efficient scale. Hence, adjusting the scale of operation could improve the efficiency. Also, technical efficiency of large scale farms were 85% and 44% for variable returns to scale and constant returns to scale, respectively. This reveals that the current level of output can be produced using 15% of less inputs on the average. It was further discovered that 46% of the 25 large scale farms were fully efficient under the variable return to scale while only 27% farms are fully efficient under the constant return to scale. It further showed that over 60%of the large scale farms did not operate at an efficient scale, hence adjusting the scale of operation could improve the efficiency. This adjustment in the scale of operation could be achieved mainly by the inclusion of scale efficiency, which the constant return to scale model did not take into account (Murthy, Sudha, Hegde and Dakshina, 2009). Therefore, the results showed that inputs usage especially by the large scale farms could be saved without harming their production. These results reconcile a sustainable management water resource which is a strategy that decreases the overexploitation of the groundwater and goes with a sustainable use of the resource.
The results further showed that size of the farms does have an impact on the efficiency of tomato output. Furthermore, the corresponding mean scale efficiency of 95% for small size farms and 85% for large size farms suggests that by operating on an optimal scale a further increase in output can be achieved beyond their projected value by as much as 5% and 15%, respectively. This implies that there is room for additional increase in domestic irrigated tomato output from existing hectares if efficiency of irrigated tomato production is enhanced. This is in agreement with Ataboh (2007) and Okoruwa, Akindeinde and Salimonu, (2009) who reported that there is room for additional increase in domestic rice output from existing hectares if efficiency of rice production is enhanced. Although the above results showed that small size farms were more efficient in terms of the technical and scale efficiency scores as it did not differ much from the corresponding estimated for large scale farms. This could probably be attributed to under-utilization of input such as fertilizer and agrochemical (pesticides) by the irrigated tomato farms. This is in agreement with Ayinde, Adewumi and Omotosho, (2009) who reported that farmers in Nigeria are yet to adopt the optimum fertilizer rate. Thus, embracing the use of fertilizer alone may not be the key to increasing tomato production levels in Nigeria, if farmers are not encouraged to adopt the optimum fertilizer rate. Encouraging farmers to adopt the optimum fertilizer rate can be accomplished through education as suggested by some studies (Llewelyn and Williams 1996; Dhungana, Nuthall and Nartea, 2004).

Table 1: Efficiency measures for irrigated tomato farms in the study area

Scale of operations	Efficient farms(θ≥0.90)		Efficiency measures			
	Freq.	**%**	**Mean**	**Standard deviation**	**Max**	**Min**
Small farms						
Technical efficiency (CRS)	35	16.5	0.66	0.23	1	0.18
Technical efficiency (VRS)	45	21.2	0.70	0.24	1	0.19
Scale efficiency (SE)	132	62.3	0.95	0.09	1	0.41
Medium farms						
Technical efficiency (CRS)	3	13.6	0.33	0.29	1	
Technical efficiency (VRS)	16	72.7	0.83	0.18	1	0.47
Scale efficiency (SE)	3	13.6	0.39	0.30	1	0.05
Large farms						
Technical efficiency (CRS)	6	27.3	0.44	0.35	1	0.07
Technical efficiency (VRS)	10	45.5	0.85	0.12	1	0.66
Scale efficiency (SE)	6	27.3	0.50	0.34	1	0.08

Regions of Operations in the Production Frontier

In addition to knowing about the number of efficient farms, extent of inefficiency and optimum scale of operation, it is also important to understand the distribution of farms in the three regions of production frontier that is how many farms are under increasing, decreasing or constant returns. The results are presented in Table 2. Approximately 55% of the farms in the small scale category were found operating in the region of increasing returns or the suboptimal region. The production scale of these farms could be increased by decreasing the costs, since they were performing below the optimum production scale. Approximately 20% of irrigated tomato farms for the small farms category, who were found operating in the decreasing returns region, could increase their technical efficiency by reducing their production levels. This region is also called as supra-optimal that is the farms were performing above the optimum scale of production. In the constant region of frontier that is the optimum scale of operation, only 24% of such small scale farms were found. Approximately 92% of the farms for the medium scale category were found operating in the region of increasing returns or the sub-optimal region. The production scale of these farms could be increased by decreasing the costs. None of the medium scale farms were found in the decreasing returns region. In the constant region of frontier, only 8% of them were found operating. Approximately 76% of the farms for the large scale category were found operating in the region of increasing returns. The production scale of these farms could be increased by decreasing the costs. None of large scale farms category were found in the decreasing returns region. In the constant region of frontier, only 24% of such farms were found operating. Given that majority of the irrigated tomato farms were operating under increasing returns to scale suggests that irrigated tomato farms were scale inefficient, since scale inefficiency is usually due to the presence of either increasing or decreasing returns to scales. This is in agreement with (Nasiru, 2010; Benjamin, Simon and Wuraola, 2011). Although in the short run, farms may operate with increasing returns to scale (IRS) or decreasing returns to scale (DRS), while in the long run however, irrigated tomato farms must shift towards constant returns to scale (CRS) to be efficient in order to achieve the desired increase in irrigated tomato production output in Nigeria.

Table 2: Distribution of irrigated tomato farms according to types of return to scale

Return to scale	IRS		DRS		CRS		Total
	Freq.	%	Freq.	%	Freq.	%	
Small farms	84	55	31	20	37	24	152
Medium farms	33	92	0	0	0	0	36
Large farms	10	76	0	0	6	24	25

CONCLUSION AND RECOMMENDATIONS

The study established that given the current level of output, small scale farms can produce output using less inputs at 30% and 34% on average. However, 21% of the 152 small scale farms are fully efficient under the variable return to scale while only 17% farms are fully efficient under constant return to scale, indicating that many over 80% of the small scale farms did not operate at an efficient scale, hence adjusting the scale of operation could improve the efficiency. Also, majority (92%) of the medium scale farms category were found operating in the region of increasing returns or the sub-optimal region (Nasiru, 2010; Benjamin, Simon and Wuraola, 2011). This is closely followed by 76% of large scale farm category. This indicates that medium and large scale farms are operating scale inefficiency or below optimum production scale. To achieve the optimum production scale, these farms could do so by decreasing the costs. It was therefore recommended that since the farms were operating below optimum production scale or scale inefficient, farmer-education should be encouraged by extension agents through effective and efficient dissemination of information.

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