



Impact of jibia dam irrigation project on wheat production and livelihood of benefiting farmers in Katsina state, Nigeria

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Abstract

Nigeria's increasing dependence on wheat imports has intensified the need for sustainable domestic production strategies, particularly in semi-arid northern regions where irrigation offers strong potential for productivity enhancement. This study evaluates the impact of the Jibia Dam Irrigation Project (JDIP) on wheat production and the livelihoods of beneficiary farmers in Katsina State using a rigorous counterfactual impact evaluation framework. A multistage sampling technique was used to select 200 wheat farmers comprising 100 beneficiaries and 100 non-beneficiaries. Primary data were collected through structured questionnaires and analyzed using descriptive statistics, logistic regression, Propensity Score Matching (PSM), Average Treatment Effect (ATE), Average Treatment Effect on the Treated (ATT), balancing diagnostics, and robustness checks. The findings reveal that irrigation participation significantly increases wheat yield by 4.3 bags per hectare (ATT, $p < 0.01$). Farm income and livelihood index also improved among beneficiaries, although welfare gains were moderated by high input costs, weak financial capital, and infrastructural limitations. The study concludes that the Jibia Dam Irrigation Project significantly enhances wheat productivity and contributes positively to farmer livelihoods; however, the magnitude of livelihood improvement is constrained by structural and institutional bottlenecks.

Keywords: Irrigation impact, wheat productivity, propensity score matching, livelihood assets, ATT, ATE, nigeria

Introduction

Agricultural productivity remains a fundamental pillar for food security, rural development, and economic stability in sub-Saharan Africa. In Nigeria, the demand for wheat has increased rapidly due to population growth, urbanization, and changing dietary preferences, while domestic production remains insufficient to meet national consumption requirements (FMARD, 2021). This widening demand-supply gap has led to heavy reliance on wheat imports, thereby exerting pressure on foreign exchange reserves and national food security.

Irrigation development has been widely recognized as a strategic intervention for enhancing crop productivity, stabilizing yields, and reducing vulnerability to rainfall variability in semi-arid environments (Hussain and Hanjra, 2004) [5]. In northern Nigeria, where rainfall is low and erratic, irrigation infrastructure plays a critical role in supporting dry-season wheat production and improving rural livelihoods (World Bank, 2021) [8].

The Jibia Dam Irrigation Project (JDIP), established under the Sokoto Rima River Basin Development Authority, was designed to promote all-season farming, improve agricultural productivity, and enhance the livelihoods of farming households in Katsina State. Despite substantial public investment in irrigation infrastructure, empirical evidence on the causal impact of such schemes using rigorous econometric approaches remains limited. Most existing studies rely on descriptive assessments that fail to address selection bias between beneficiaries and non-beneficiaries (Caliendo and Kopeinig, 2008; Rosenbaum and Rubin, 1983) [2, 7].

Therefore, this study evaluates the impact of the Jibia Dam Irrigation Project on wheat productivity and household livelihood outcomes using Propensity Score Matching (PSM), ATT, ATE, and robustness diagnostics to provide credible causal inference.

Literature Review

Irrigation enhances agricultural productivity by ensuring reliable water supply, increasing cropping intensity, and reducing exposure to climatic risks (Hussain and Hanjra, 2004) [5]. Empirical evidence suggests that irrigation investments significantly improve crop yield, farm income, and food security in semi-arid regions (Burney *et al.*, 2013) [1].

However, public irrigation schemes in developing countries often face infrastructural decay, weak institutional governance, and limited farmer participation, which constrain their effectiveness (Inocencio *et al.*, 2007) [6]. Moreover, productivity gains from irrigation do not automatically translate into improved household welfare due to high input costs, market inefficiencies, and limited financial access (Fan *et al.*, 2008) [3].

Impact evaluation techniques such as Propensity Score Matching (PSM) provide robust estimates of program effects in non-randomized settings by addressing selection bias and ensuring valid counterfactual comparison (Rosenbaum and Rubin, 1983; Caliendo and Kopeinig, 2008) [2, 7]. These approaches have become increasingly important in evaluating agricultural interventions and irrigation programs in developing economies.

Methodology

1. Study Area

The study was conducted in Jibia Local Government Area of Katsina State, Nigeria, located within the Sudan Savannah ecological zone characterized by low rainfall, high temperature, and strong dependence on irrigation for dry-season farming.

2. Sampling Technique and Data Collection

A multistage sampling technique was adopted. Three beneficiary communities within the irrigation command area and three comparable non-beneficiary communities were selected. A total of 200 wheat farmers (100 beneficiaries and 100 non-beneficiaries) were sampled. Primary data were collected using structured questionnaires complemented by field observations.

3. Econometric Impact Evaluation Framework

Logit Model for Participation

$$P(X_i) = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}}$$

Treatment Effect Estimators

$$ATT = E(Y_1 - Y_0 | T=1), ATE = E(Y_1 - Y_0 | T=1) - E(Y_1 - Y_0 | T=0)$$

Nearest Neighbour, Kernel, and Radius matching algorithms were applied to ensure robustness of the treatment effect estimates (Caliendo and Kopeinig, 2008) [2].

Results and Discussion

Table 1: Socioeconomic Characteristics of Wheat Farmers

Variable	Beneficiaries	Non-Beneficiaries	t-value
Age (years)	44.2	45.7	1.12
Education (years)	9.8	7.3	3.21***
Farm size (ha)	2.4	1.8	2.54**
Farming experience (years)	16.5	14.2	2.07**
Extension access (%)	68	41	4.02***
Credit access (%)	52	29	3.76***

The results indicate that beneficiary farmers are relatively more educated, operate larger farm sizes, and have greater access to extension and credit services than non-beneficiaries. These observable differences suggest non-

random participation in the irrigation scheme and justify the application of PSM to correct for selection bias (Rosenbaum and Rubin, 1983) [7].

Table 2: Determinants of Irrigation Participation (Logit Model)

Variable	Coefficient	Std. Error	z-value
Education	0.083**	0.037	2.24
Farm size	0.291***	0.078	3.73
Extension contact	0.512***	0.142	3.60
Credit access	0.438**	0.171	2.56
Pseudo R ²	0.31		

Education, farm size, extension contact, and credit access significantly influence irrigation participation. This implies that human capital, institutional support, and resource endowment are critical determinants of adoption of

irrigation technologies, consistent with findings from irrigation impact studies in developing countries (Inocencio *et al.*, 2007; World Bank, 2021) [6, 8].

Table 3: PSM Balancing Diagnostics

Indicator	Before Matching	After Matching
Mean bias (%)	26.8	4.3
Pseudo R ²	0.31	0.04
LR test (p-value)	0.000	0.509

The substantial reduction in mean bias and pseudo R² after matching confirms strong covariate balance between treated and control groups. The insignificant LR test after matching indicates that systematic differences between beneficiaries

and non-beneficiaries were effectively minimized, validating the reliability of the counterfactual analysis (Caliendo and Kopeinig, 2008) [2].

Table 4: Impact of JDIP on Wheat Productivity and Livelihood (ATT & ATE)

Outcome Variable	ATT	Std. Error	Significance
Wheat yield (bags/ha)	4.30	0.92	***
Farm income (₦)	96,500	28,740	***
Livelihood Index	0.118	0.031	***

The ATT estimate shows that irrigation participation increases wheat yield by approximately 4.3 bags per hectare, demonstrating the strong productivity-enhancing

effect of irrigation access in semi-arid environments. This finding corroborates empirical evidence that irrigation stabilizes yields and improves agricultural output under

water-scarce conditions (Hussain and Hanjra, 2004; Burney *et al.*, 2013)^[1,5].

Although income and livelihood index improved significantly, the magnitude of welfare gains remained

moderate due to rising input costs and limited financial capital, supporting the argument that productivity gains do not automatically translate into proportional livelihood transformation (Fan *et al.*, 2008)^[3].

Table 5: Robustness Checks across Matching Algorithms

Matching Method	ATT (Yield)
Nearest Neighbour	4.30***
Kernel Matching	4.12***
Radius Matching	3.98***

The consistency of ATT estimates across multiple matching algorithms confirms the robustness and stability of the estimated treatment effects, thereby strengthening the causal validity of the irrigation impact results (Caliendo and Kopeinig, 2008)^[2].

Table 6: Livelihood Asset Index (LAI)

Capital Asset	Index Score
Human Capital	0.52
Social Capital	0.74
Physical Capital	0.38
Financial Capital	0.29
Natural Capital	0.43
Overall LAI	0.47

The Livelihood Asset Index reveals strong social capital among beneficiary farmers, reflecting effective cooperative networks and communal participation within the irrigation scheme. However, weak financial and physical capital indicate limited access to credit and deteriorating irrigation infrastructure. These structural constraints explain why productivity gains from irrigation do not fully translate into substantial livelihood improvements, a pattern widely documented in public irrigation schemes in sub-Saharan Africa (Inocencio *et al.*, 2007; World Bank, 2021)^[6,8].

Conclusion

This study provides rigorous empirical evidence on the impact of the Jibia Dam Irrigation Project on wheat production and farmer livelihoods in Katsina State using a counterfactual econometric framework. The findings demonstrate that irrigation participation significantly increases wheat productivity, with an estimated ATT of 4.3 bags per hectare, confirming the critical role of irrigation in enhancing agricultural performance in semi-arid environments.

The project also contributes positively to farm income and livelihood outcomes; however, the extent of welfare improvement remains constrained by high input costs, weak financial capital, and infrastructural limitations. The Livelihood Asset Index further reveals structural imbalances, with strong social capital but weak financial and physical assets among beneficiary farmers.

Overall, the Jibia Dam Irrigation Project significantly promotes agricultural productivity and livelihood improvement, but its full developmental potential is moderated by economic, institutional, and infrastructural bottlenecks that limit sustainable welfare gains.

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