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Analysis of Impact of International Fund for Agricultural Development Rice Value Chain Programme Technological Adaptation on Output of Beneficiary Rice Farmers in Benue State, Nigeria

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Abstract

The study investigated the impact of International Fund for Agricultural Development Rice Value Chain Programme (IFAD-VCDP) technological adaptation on output of beneficiary rice farmers in Benue State, Nigeria. The study used a survey design and selected 348 beneficiary rice farmers for the investigation. Structural Equation Modeling (SEM) was used as an analytical technique. Findings of the study revealed that all the three technologies introduced by IFAD-VCDP, namely; tilers, sprayers and harvesters had positive and statistically significant impact on technological adaptation of the beneficiary rice farmers and technological adaptation in turn had positive and statistically significant on the rice output of the beneficiaries in the study area. On the basis of the findings of the study, the following recommendations were made. First, IFAD-VCDP should strengthen farmers' access to inputs and mechanization especially technologically based farm inputs and IFAD-VCDP should scale up training in agronomic practices and agribusinesses to build the farmers' capacities significantly to improve farmers' confidence for technological adaptability that will enhance utilization of farm inputs optimally.

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Introduction

Technological adaptation in agriculture propels agricultural production by helping farmers to optimize inputs that increase yields. Agricultural technologies have long been promoted by governments and development organizations as effective ways to increase farm productivity and reduce poverty. According to agricultural technology has to do with the equipment, genetic material, farming techniques, and agricultural inputs that have been developed to improve the effectiveness of agriculture. Modern agricultural technologies are crucial for addressing global food security and environmental sustainability challenges amidst a growing population and climate change. These innovations, including precision agriculture, biotechnology, smart irrigation, automation, vertical farming, and artificial intelligence (AI), significantly enhance productivity and land use efficiency [1,4,18].

The International Fund for Agricultural Development (IFAD) promotes technological adaptation in smallholder agriculture by investing in climate-resilient practices and innovative digital tools to increase productivity, build resilience to climate change, and enhance market access. IFAD has Flagship Programmes for technological adaptation, these include: Adaptation for Smallholder Agriculture Programme (ASAP), Innovatech and Agricultural Research for Development (AR4D). By integrating these technologies and approaches, IFAD aims to transform smallholder farming from subsistence to commercially viable enterprises, ensuring food security. IFAD helps small-scale farmers in developing countries adapt to climate change and build resilient livelihoods by providing them with knowledge, skills and technology [7].

In order to upscale the productive capacity of small-scale farmers and reduce poverty among these groups of farmers in Nigeria, the IFAD in collaboration with the three tiers of government via the Value Chain Development Programme (VCDP) developed a six-year plan for improving cassava and rice value chain of small-scale farmers using technologies in nine states; namely; Anambra, Benue, Ebonyi, Niger, Ogun, Taraba, Enugu, Kogi and Nasarawa States [7].

In Benue State, the IFAD Value Chain Development Programme (VCDP) covers eight Local Government Areas: namely, Okpokwu, Logo, Gwer East, Guma, Ogbadibo, Gwer West, Kwande and Agatu local government areas. The programme started in the State in 2015 and over 17,392 beneficiaries have directly benefited from the programme from 2015 to 2023 for the production, processing and marketing of rice and cassava in the state.

Since the commencement of IFAD Value Chain Development Programme (VCDP) in Nigeria, numerous studies have been conducted to investigate the impact of the programme on rice production in different beneficiary states in Nigeria. For instance, studies by Taibat, Bello, Musa & Shehu (2015), Shehu, Ndanitsa, Ojo & Sadiq (2019), Sadiq, Singh & Ahmad (2020), Ndanitsa, Musa, Ndako &Mohammed (2020), Oruonye, Tukura & Menwo (2021), Sadiq, Singh, Ahmad, Yunsa & Egba (2021), Tsado, Mohammed & Pelemo (2022), Obianefu, Okoroji & Obiekwe (2022), Orjime, Abaa, Shember & Asombo (2023) have severally examined the impact of IFAD-VCDP on rice output and incomes of beneficiary rice farmers in different states in the country. However, these studies did not consider the role of technological adaptation in the operations of IFAD in country [2,4].

In view of the fact that technological adaptation is key in the operations of IFAD-VCDP, this current study has specifically focused on the impact of technological adaptation on the output of beneficiary rice farmers in Benue State, Nigeria.

Methodology of the Study

Study Area

The study area of this study is Benue State. Benue State is located in north-central Nigeria. It falls within Longitudes 7o 47’ and 10o 00’ East, and Latitudes 6o 25’ and 8o 8’ North and occupies an area of 34, 059 square kilometers (see Fig.1). It is bounded to the North by Nasarawa State, to the North-East and East by Taraba State, to the West by Kogi State, to the South West by Enugu State, to the South-East by the Republic of Cameroun and to the South by Ebonyi and Cross River states.

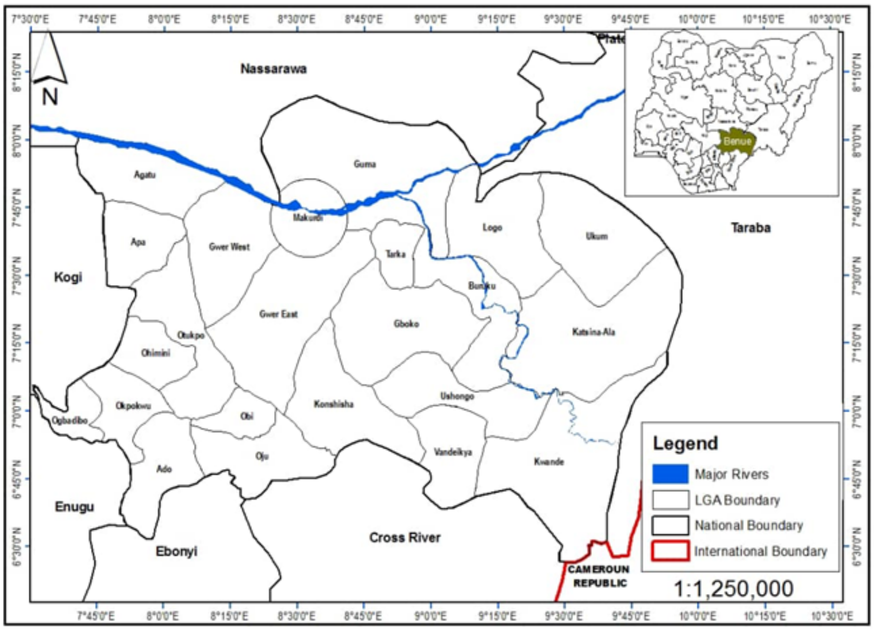

Figure 1: Benue State showing the twenty-three Local Government Areas
Source: Benue State University GIS Lab.

The State is made up of twenty-three Local Government Areas that occupy a total landmass of 45, 174 Square Kilometers (Lyam, 1995). Fourteen (14) of the Local Government Areas correspond with the region dominated by the Tiv tribe while seven (7) Local Governments are known as Idomaland and two (2) are referred to as Igedeland.

Benue State is drained mainly by Rivers Benue and Katsina-Ala. There is a dense network of tributaries of these two major rivers that traverse the entire length and breadth of the state. Such rivers include Amire, Mu, Okpokwu, Ochekwu, Ohimini, Dura, Aya, Mkomon, Oyongo, Konshisha, Ushongo, Sambe, Loko, Onagi, Otobi, Ogede, Ombi, and Ogori (Nyagba, 1995). Most of the smaller rivers in the State dry up completelyfor most of the year while the volume of the few large and permanent rivers fluctuates considerably with seasons.

Agriculture forms the backbone of the State's economy engaging over 70% of the labour force (Nyagba, 1995). Virtually all rural households are involved in some form of agriculture which could be subsistence crop farming, livestock keeping or cash crop production. The commonly agricultural commodities of the State include yam, rice, cassava, soya beans, guinea corn, tomatoes, pepper, ginger, sweet potatoes, maize, and groundnuts. For citrus, the State largely produces oranges, mangoes, and cashews. Though the farms are generally small (ranging from less than one hectare to more than six hectares) and the agricultural system is largely rain-fed and un-mechanized, total crop yield is generally impressive due to the large number of small scale farmers.

The population of this study comprise all the rice farmers, rice processors and marketers who are the direct beneficiaries of IFAD/VCDP in the eight Local Government Areas: namely, Okpokwu, Logo, Gwer East, Guma, Ogbadibo, Gwer West, Kwande and Agatu local government areas from 2019 to 2023. The number of beneficiaries are presented in the following table.

Table 1: Number of Rice Beneficiaries of IFAD-VCDP in Benue State from 2019 to 2023

LGA	2019		2020		2021		2022		2023	
	FOs	Beneficiaries	FOs	Beneficiaries	FOs	Beneficiaries	FOs	Beneficiaries	FOs	Beneficiaries
Agatu	19	410	22	195	3	53	1	11	2	17
Guma	20	99	37	289	0	0	0	9	6	35
Gwer East	16	90	41	344	3	51	1	15	2	20
Gwer	26	477	38	278	13	102	1	8	6	10
West										
Logo	9	84	27	290	3	31	1	19	2	9
Kwande	23	355	50	661	6	49	1	30	1	20
Ogbadibo	0	0	0	0	0	0	1	0	0	0
Okpokwu	1	20	8	36	1	10	0	8	1	11
Total	114	1535	223	2093	29	296	6	100	20	122

Source: IFAD Benue Office; (2024)

From the table, there is a total of 4,146 rice beneficiaries of IFAD-VCDP in Benue State from 2019 to 2023.

Sampling Procedure

The study has employed a multi-stage sampling procedure. In the first stage, the study purposively selected three local government areas in the state, one from each of the geo-political areas of Benue State. That is, Kwande from Zone A, Gwer West from Zone B and Agatu from Zone C. The choice of these local government areas among other benefiting LGAs is because, these LGAs have the highest numbers of rice direct beneficiaries of the IFAD/VCDP. That is, Kwande has 1,115; Gwer West has 875; and Agatu has 686. These sum up to a total of 2,676 direct beneficiaries of rice who now constitute the sampling frame.

Using this sampling frame, the Taro Yammene's formula was used to determine obtain the optimal sample size for the investigation. The formula is stated as:

$$n = \frac{N}{1+N(e^2)} \quad \text{..........1.}$$

Where n is the desired sample size, e is the level of significance, N is the study's population of beneficiaries of the IFAD/VCDP in selected LGAs.

Thus $$n = \frac{2,676}{1+2,676(0.05^2)} = 348$$

Therefore, the optimal sample size of the beneficiaries of the IFAD/VCDP in the selected LGAs for this study is 348 beneficiaries.

Furthermore, the Boyce's allocation formula was used to determine the proportions of rice farmers in the determined sample size of 348 as follows:

$$\text{For Kwande} = \frac{1,115}{2,676} \times 348 = 145 \text{ Rice beneficiaries}$$

$$\text{For Gwer West} = \frac{875}{2,676} \times 348 = 114 \text{ Rice beneficiaries}$$

$$\text{For Agatu} = \frac{685}{2,676} \times 348 = 89 \text{ Rice beneficiaries.}$$

In the second stage, a cluster sampling procedure was applied to select the determined 348 rice direct beneficiaries in the three LGAs. The choice of the cluster sampling technique is deemed most appropriate in this study because the beneficiaries of the IFAD/VCDP are grouped into clusters called Farming Organizations (FOs) also known as Cooperatives. Kwande has 81 FOs, Gwer West has 84 FOs and Agatu has 47 FOs. In so doing, 50% of FOs in each LGA was randomly selected. That is, 41 FOs for Kwande, 42 FOs for Gwer West and 24 FOs Agatu. Approximately, 107 FOs will be selected for investigation.

In the last stage, random sampling procedure was used to select the direct rice beneficiaries from the selected FOs. For Kwande, the145 direct beneficiaries rice were randomly selected from the 41 sampled FOs; For Gwer West the 114 direct rice beneficiaries were randomly selected from the 42 sampled FOs and for Agatu, the 89 direct rice beneficiaries rice were randomly selected from the 24 sampled FOs using the Microsoft excel inbuilt random sampling mechanism.

Finally, the excel random samples generated was used to trace the locations and contacts of the selected beneficiaries for questionnaire administration.

Methods of Data Collection

The data for this study were collected using structured questionnaire and in-depth interviews. Copies of questionnaire were administered on the beneficiary rice farmers. The FOs heads of the various cooperatives assisted in the questionnaire administration; while the in-depth interviews were conducted with IFAD-VCDP's officials in Benue State.

Methods of Data Analysis

The method of data analysis is the Structural equation modeling (SEM). The Structural equation modeling (SEM) is a multivariate statistical framework that is used to model complex relationships between directly observed and indirectly observed (latent) variables. SEM is a general framework that involves simultaneously solving systems of linear equations and encompasses other techniques such as regression, factor analysis, path analysis, and latent growth curve modeling. Structural Equation Modeling (SEM) is superior to traditional methods like multiple regression or path analysis primarily due to its ability to model complex relationships involving latent variables (unobserved constructs) and to account for measurement error (Stein, Morris, Hall & Nock; 2017).

In order to examine how the adaptation of IFAD technologies and practices have affected rice production among IFAD-VCDP beneficiary in Benue State, Structural Equations Models (SEMs) were calibrated.

The SEMs' critical path is presented in the following figure. First, the SEM is calibrated to capture the adaptation of technologies introduce by the IFAD rice value chain for the production of rice at the farm level. This involves the provision of inputs like Tillers, Sprayers for pesticides, herbicides and fertilizer applications and harvesters and this presented in Figure 1

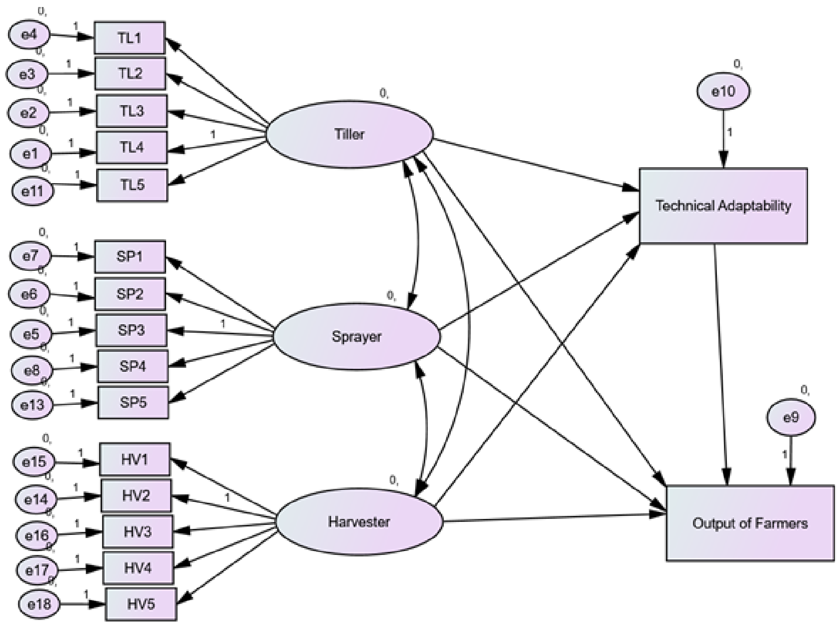

Figure 1: SEM Critical Path Showing the Adaptation of IFAD Technologies and its impact on Rice Output of Beneficiary Farmers

The structural equation model (SEM) developed for this study explores the integrated influence of Tiller (TL), Sprayer (SP), and Harvester (HV) on the output of rice farmers (OF), with technical adaptability (TA) acting as a mediating observed variable. The final model specification was refined to achieve statistical adequacy and theoretical coherence by including only indicators with strong psychometric properties. Specifically, only indicators with standardized factor loadings greater than 0.7 were retained, except for SP3 and HV3, which were excluded to improve model performance. These exclusions reflect poor measurement quality or conceptual misalignment with the underlying latent constructs. This ensures the measurement model has both convergent and discriminant validity, which is essential for robust SEM estimation.

The latent construct of Tiler (TL) comprises five indicators reflecting infrastructure and training associated with the tiling machines, such as access to tiler during the IFAD project (TL1), the usage of tiling machine (TL2), years of usage of tiler under IFAD-VCDP (TL3), tiler use-related training received through IFAD (TL4) and the cost associated with the use of tiler (TL5). All these indicators exhibited high factor loadings, demonstrating that they strongly and uniquely represent the latent construct of TL. This construct reflects the extent to which IFAD's interventions have structured and enhanced local tiling operations among farmers.

The Spraying Machine (SP) construct is measured using four reliable indicators following the removal of SP3, which had poor loading. The retained items were SP1 (access to spraying machine during IFAD), SP2 (the usage of spraying machine), SP4 (years of usage of spraying machine under IFAD-VCDP), and SP5 (technical training received about the use of sprayer under IFAD-VCDP). All of these showed factor loadings exceeding 0.7. The exclusion of SP3 is theoretically justifiable as it may have been too ambiguous or overlapping with other items. Additionally, to improve model fit, covariance between SP2 and SP4, and between SP4 and SP5, was introduced as suggested by the modification indices. These covariances reflect underlying relationships between years of experience, training, and equipment capacity — conceptually consistent with real-world learning and infrastructure development interactions.

Similarly, Harvesters (HV) was assessed through five original items, but HV3 was dropped due to low factor loading. The retained indicators, HV1 (access to Harvester during IFAD) and HV2 (Usage of Harvesters during IFAD-VCDP) HV4 (training received on Harvester usage), HV4 (years of usage of Harvester under IFAD-VCDP).

Technical Adaptability (TA) was modeled as an observed variable, created by computing a composite average of five distinct items (TA1 through TA5), including participation in training, use of improved techniques, perceived quality improvement, post-harvest loss reductions, and years of processing experience. These variables together capture the concept of adaptability as the farmer's capacity to integrate and apply knowledge and practices obtained from IFAD-VCDP initiatives. As a mediating variable, TA links the infrastructural and human capital investments of PP, MM, and DS with actual performance outcomes (OP).

Output of rice (OP), also treated as an observed composite variable. From a structural perspective, the SEM tests the direct effects of the three exogenous latent constructs (TL, SP, HV) on TA, and then the indirect effects of these constructs on OP via TA. TA, therefore, serves as the mediator, reflecting how technical competency and adaptability convert infrastructure, training, and equipment into measurable productivity outcomes. In the final path model, all paths from latent variables to TA were statistically significant, with standardized path coefficients well above conventional thresholds, confirming the mediating role of TA. The direct path from TA to OP was also strong and significant, confirming the expectation that higher adaptability leads to increased productivity. This finding aligns with theories in technology adoption and capacity-building frameworks which posit that the pathway to performance is not only through physical investment but through knowledge integration and skill application.

To account for potential overlap among the predictors, covariances were established between the exogenous latent constructs TL, SP, and HV, as they may share overlapping sources of variance for instance, IFAD training sessions could simultaneously influence multiple areas such as tiling and harvesting. These covariances also help stabilize the estimation of regression paths and improve model fit by addressing multicollinearity at the structural level. Thus, the final SEM specification provides a statistically robust and theoretically coherent representation of how IFAD-VCDP interventions in infrastructure (tiling and spraying), equipment (harvesting), and training translate into improved processor outputs through the mediating role of technical adaptability

Empirical Results

First, the socio-economic characteristics of the respondents are presented in Table 2.

Table 2: Socio-Economic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Age	<30	89	25.57
	30–39	104	29.89
	40–49	67	19.25
	≥50	88	25.29
Total		348	100
Sex	Male	164	47.13
	Female	184	52.87
Total		348	100
Farm Size	01-May	79	22.7
	06-Oct	136	39.08
	Nov-15	73	20.98
	≥15	60	17.24
Total		348	100
Educational Level	None	39	11.21
	Primary	126	36.21
	Secondary	176	50.57

	Tertiary	7	2.01
Total		348	100

Table 2 shows the socio-economic characteristics of the sampled beneficiary rice farmers in the study area. The table reveals that a majority of the sampled beneficiaries are between 30–39 years. This suggests that majority of the beneficiary rice farmers are in their youthful and productive age bracket.

Also, the results showed that 164 sampled beneficiaries representing 47.13% are male and 184 beneficiaries representing 52.87% are female. This suggests that IFAD-VCDP takes into cognizance issues of gender inclusivity in selecting the beneficiaries of the programme. Furthermore, the table indicates that majority of the beneficiaries have their farm size ranging from 6 to 10 hectares of rice farm. This suggests that beneficiaries of IFAD-VCDP have relatively large rice farms.

For educational attainment, majority of the beneficiaries, that is, 176 beneficiaries representing 50.57% have indicated that secondary school is their highest educational qualification. This also reflects the character of a typical farming population where people go to school just to know how to read and write.

Next, the impact of IFAD-VCDP technological adaptation on output of the beneficiaries was examined using the SEM. The impact of IFAD-VCDP on technological adaptation on output was done starting with the Factor Loadings and Construct Reliability test. The Confirmatory Factor Analysis (CFA) was used to validate the measurement structure underpinning the latent constructs influencing farmers' output in the context of IFAD-supported technologies in Benue State. The key constructs in focus were Tiller (TL), Sprayer (SP), and Harvester (HV) as predictors of Technical Adaptability (TA), which in turn was modeled as a mediator impacting the Output of Farmers (OP). Each of these latent constructs was operationalized through several observed variables that were subjected to CFA to ensure they had sufficient loading strength. Indicators with factor loadings below 0.50 or those responsible for excessive model misfit were eliminated to ensure construct parsimony and integrity. All constructs demonstrated strong standardized factor loadings above the minimum threshold of 0.50, confirming adequate item reliability. The Average Variance Extracted (AVE) exceeded 0.50 for all constructs, confirming convergent validity. Additionally, Composite Reliability (CR) values surpassed the 0.70 benchmark, indicating robust internal consistency. Discriminant validity, assessed through the Fornell-Larcker criterion, revealed that the square root of each construct's AVE was greater than its correlation with other constructs, confirming that each construct was empirically distinct.

Next, the Construct validity was established through the dual evaluation of convergent and discriminant validity. The strong AVE and CR values confirmed that the measurement items accurately represented their intended constructs (convergent validity), while all inter-construct correlation coefficients remained below the 0.90 threshold and did not violate discriminant validity conditions. The model also passed diagnostic checks for multivariate normality, outliers, and multicollinearity. No multicollinearity was detected as no correlations between latent constructs exceeded the 0.90 threshold, and the Mahalanobis distance confirmed no severe outlier influence.

For the Model Fit, the Goodness-of-Fit (GOF) indices supported the adequacy of the measurement model. The chi-square value ($\chi^2 = 305.76$, df = 111) yielded a χ^2/df ratio of 2.755, which falls within the acceptable threshold (<3.0), indicating good model parsimony. Incremental fit indices further validated the model: CFI = 0.909, IFI = 0.901, and TLI = 0.902, all of which exceed the 0.90 benchmark, confirming strong relative fit over a null model. Although, NFI = 0.858 and RFI = 0.808 were slightly below ideal levels, they remain acceptable when viewed alongside the stronger indices. The RMSEA = 0.064 and SRMR = 0.0342 are both within the recommended thresholds (<0.08), confirming a good approximate fit of the model in the population. Overall, the model demonstrates solid psychometric validity and is fit for structural path analysis. Thus, the structural path analysis is presented in the following figure:

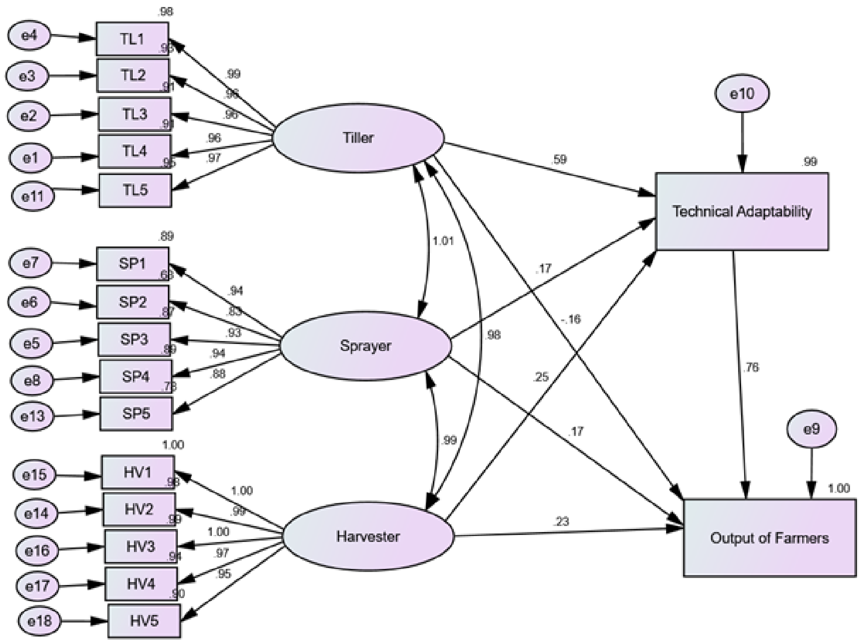

Figure 2: Structural Path Analysis for IFAD-VCDP Beneficiary Farmers

The structural path model tested the hypothesized relationships between IFAD-introduced technologies Tiller (TL), Sprayer (SP), and Harvester (HV) and their effects on Technical Adaptability (TA) and Farmer Output (OF). Maximum Likelihood estimation was used to evaluate the direct and indirect effects of the independent variables, with technical adaptability acting as a key mediator. Critical ratios (C.R.), standardized estimates, standard errors (S.E.), and p-values were used to determine significance.

The relationship between tiller usage and technical adaptability was found to be highly significant and positive (Unstandardized Estimate = 0.585, Standardized Estimate = 0.82, C.R. = 11.731, $p < 0.001$). This indicates that access to and usage of tillers significantly enhance a farmer's ability to adjust to and utilize modern mechanized systems. Tillage equipment often forms the foundation of land preparation and directly correlates with mechanization literacy, making this result both statistically and practically meaningful. Sprayers also demonstrated a significant and positive effect on technical adaptability (Standardized Estimate = 0.218, C.R. = 3.489, $p < 0.001$). While less impactful than tillers, this result emphasizes the role of crop protection technology in equipping farmers with operational knowledge and willingness to integrate diverse agricultural machinery. The moderate effect size reflects that sprayers are often easier to use and may act as stepping stones toward embracing more complex technologies. Similarly, harvesters had a significant and positive relationship with technical adaptability (Standardized Estimate = 0.242, C.R. = 8.296, $p < 0.001$). The mechanization of post-harvest activities, traditionally labour-intensive, signals advanced technological uptake. Farmers using harvesters are more likely to demonstrate broader operational skills and flexibility in adapting to time-saving and yield-preserving tools.

Incidental findings also show a surprising result, the direct effect of tillers on farmer output was negative and statistically significant (Standardized Estimate = –0.221, C.R. = –3.625, $p < 0.001$). This counterintuitive result suggests that while tillers improve adaptability, they may not directly boost output unless used in conjunction with complementary practices or other technologies. Possible interpretations include improper use, soil-type mismatch, or time lags in realizing productivity benefits. It reinforces the idea that technological inputs must be aligned with agronomic practices to yield tangible gains. Sprayers were shown to have a positive and statistically significant effect on output (Standardized Estimate = 0.221, $p < 0.001$), emphasizing their role in pest and weed management and yield preservation. This reinforces the importance of chemical application tools in crop protection and productivity, particularly in regions facing pest outbreaks or variable climatic conditions.

Harvesters also had a significant positive effect on output (Standardized Estimate = 0.222, $p < 0.001$). Mechanized harvesting reduces post-harvest losses and turnaround time, which directly boosts efficiency and net output. In resource-constrained farming environments like Benue, such technologies can be transformative by minimizing crop damage and improving harvest timeliness.

Perhaps the most influential relationship in the model is the strong, positive, and statistically significant link between technical adaptability and farmer output (Standardized Estimate = 0.759, C.R. = 20.938, $p < 0.001$). This explains the central role of adaptability in converting technology into performance. Farmers who are more adaptable and willing to engage with new tools, techniques, and processes are better positioned to optimize yields and productivity. This mediating effect also helps explain why certain technologies like tillers may not show strong direct output effects but contribute meaningfully through increased technical capacity. Technical Adaptability acts as the bridge between technology and productivity. IFAD's technology diffusion efforts particularly sprayers and harvesters have had a direct and positive effect on farmers' output. Tillage equipment, despite its strong contribution to adaptability, shows a negative direct effect on output, suggesting that its benefits may be contingent upon farmer skill, field condition, or paired technology use. The model fit indices (CFI = 0.909, IFI = 0.901, TLI = 0.902) and $\chi^2/df = 2.755$ all affirm that the specified model fits the data well. With RMSEA = 0.064 and SRMR = 0.0342, residuals remain minimal, strengthening confidence in the conclusions drawn. These results suggest that for IFAD programs to sustain and scale success, emphasis must be placed not only on access to tools but also on farmer training, after-sales service, and operational guidance.

The adaptation of IFAD-supported technologies and practices has had a transformative impact on rice production in Benue State, as evidenced by the structural equation modelling results analyzing the relationships between mechanization inputs, farmer adaptability, and output. IFAD's intervention focused on enhancing mechanization access through the provision of equipment such as tillers, sprayers, and harvesters has significantly influenced both the capacity of rice farmers to adopt new technologies (technical adaptability) and their actual output levels. This strategic combination of infrastructural support and knowledge transfer explains IFAD's value-chain approach to agricultural development, particularly in resource-limited environments like Benue State.

The findings clearly demonstrate that technical adaptability plays a central mediating role in translating technology into productivity. All three technologies tillers, sprayers, and harvesters had strong, statistically significant positive effects on farmers' technical adaptability. The tiller, for instance, exhibited the highest standardized effect ($\beta = 0.82$), indicating that access to land preparation equipment has substantially elevated farmers' readiness and capacity to adopt modern methods. Likewise, the harvester and sprayer, with standardized effects of 0.242 and 0.218 respectively, contributed meaningfully to the development of mechanized know-how. These results suggest that IFAD's technology infusion has not merely introduced physical tools but has cultivated a culture of learning and adaptability, where farmers are increasingly comfortable using complex equipment and integrating them into their production cycles.

However, the direct relationship between these technologies and rice output reveals a sounder picture. Technical adaptability itself emerged as the most powerful predictor of increased rice output ($\beta = 0.759$, $p < 0.001$). This suggests that farmers who became more adept at using technology thanks to their exposure to IFAD equipment were better able to optimize land use, control weeds and pests, and manage harvest operations efficiently, all of which are crucial for boosting yields and reducing post-harvest losses. The data supports the idea that technology alone is not sufficient; it is the capacity to adapt and use the technology effectively that drives impact. This reinforces IFAD's model of pairing equipment deployment with training and capacity building.

Interestingly, the direct effects of the technologies on output varied. Harvesters ($\beta = 0.222$) and sprayers ($\beta = 0.221$) had significant and positive direct effects on rice output, which affirms their practical utility in post-harvest and pest management processes respectively. These technologies likely contributed to higher efficiency, cleaner grain, and better harvest timing, leading to real output gains. In contrast, the tiller had a negative direct effect on output ($\beta = -0.221$), a result that may seem counterintuitive but is revealing. It suggests that while tillers greatly enhance technical adaptability, they may not independently lead to better output unless properly used in conjunction with other technologies or agronomic best practices. Factors such as improper tillage depth, poor timing, or inadequate soil suitability may limit the benefits of mechanized land preparation. Therefore, the data highlights that without targeted training, even well-intended mechanization can underperform. Thus, IFAD's interventions have significantly advanced rice production in Benue State by increasing farmers' technical adaptability and equipping them with high-impact machinery. The positive chain of influence from technology access to improved skills, and from skills to output illustrates the strength of IFAD's integrated approach. The only caveat emerging from the study is the importance of contextualizing technology deployment: not all tools deliver immediate gains unless paired with knowledge, training, and ongoing support services.

Conclusion and Policy Recommendations

On the basis of the findings of this study, it was concluded that all the three IFAD-VCDP technologies introduced, namely; tillers, sprayers and harvesters had strong positive effects on beneficiary rice farmers' technical adaptability and output of rice in the study area. Therefore, the study has made the following recommendations:

First, IFAD-VCDP should strengthen farmers' access to inputs and mechanization especially technologically based farm inputs. This is because input provision and mechanization support under IFAD-VCDP showed increase yields. This can be achieved through timely input delivery before planting season; establishment of commodity managed input depots; and shared use models for tilers and harvesters among cooperative groups.

Also, IFAD-VCDP should scale up training in agronomic practices and agribusinesses to build the farmers' capacities significantly to improve farmers' confidence for technological adaptability that will enhance utilization of farm inputs optimally. This can be achieved through: Partnership with local extension agents and agro-allied NGOs to deliver modular training on utilization of modern farm technologies, improved seed varieties, climate-smart practices, business planning and financial literacy; and inclusion of Peer-to-Peer learning systems for knowledge sustainability

References

1. Adeyemo JT, Ahmed A, Abaver DT, Riyadh HA (2024) Technological Innovation and Agricultural Productivity in Nigeria Amidst Oil Transition: ARDL Analysis. Economies 12:253.
2. Bamidele T, Olayide O, Onigbinde D (2019) Assessing IFAD value chain development programme on productivity and incomes of smallholder farmers in Obafemi-Owode and Yewa North local government areas of Ogun State, Nigeria. African Journal of Sustainable Development 9:27-39.
3. Chen X (2025) The role of modern agricultural technologies in improving agricultural productivity and land use efficiency. Frontier in Plant Science.
4. Enenchi T, Ojiagu N (2021) International fund for agricultural development (IFAD) value chain development programme and rice yield: A study of members of rice farmers' co-operative in Anambra State, Nigeria. International Journal of Academic Management Science Research (IJAMSR) 5: 76-86.
5. Gebeyehu M (2016) The impact of technology adoption on agricultural productivity and production risk in Ethiopia: Evidence from rural Amhara household survey. Open Access Library Journal 3: 1-14.
6. IFAD (2018) IFAD Policy on Improving Access to Land and Tenure Security. Retrieved from: www.ifad.org/gbdocs/eb/94/e/EB-2008-94-R-2-Rev-1.pdf.
7. 7. IFAD (2022) IFAD's Environment and Natural Resource Management Policy: Resilient livelihoods through the sustainable use of natural assets www.ifad.org/gbdocs/eb/102/e/EB-2011-102-R-9.pdf.
8. International Fund for Agricultural Development (IFAD) (2015). Rural poverty report: The challenges of ending rural poverty. New York: Oxford University Press Inc.
9. Michhurina N, Amosova A, Kosnikov S, Vasilieva D, Kholopov Y (2024) Adaptation of agricultural technologies to climate change: Ways to reduce environmental impact. E3S Web of Conference 510.
10. Ndanitsa M A, Musa S E, Ndako N, Mohammed D (2020) Effect of value chain development programme on small-scale rice farmers in Niger State, Nigeria. Badeggi Journal of Agricultural Research and Environment 2: 84-96.

11. Obianefo A C, Okoroji O N, Obiekwe J N (2022) The effect of value chain financing on rice farmers' efficiency in IFAD assisted value chain development programme in Awaka. International Journal of Life Science Research Archive 3: 144-154.
12. Oruonye E D, Turkura E D, Menwo U W (2021) The impact of IFAD –Value chain Development programmme on rice yield and income among small holders' farmers in Ardo-Kola LGA, Taraba state, Nigeria. Journal of Agricultural Science and Food Technology 7: 66-74.
13. Sacha R, Ricardo L, Amy B (2021) Adoption of agricultural technology in the developing world: A meta-analysis of empirical literature. World Development 146: 235-245.
14. Sadiq M S, Singh I P, Ahmad M M (2020) Effect of IFAD-VCDP on input - output commercialization of rice farmers in Niger State of Nigeria. Alinters Journal of Agricultural Science 35: 51-58.
15. Sadiq M S, Singh I P, Ahmad M M (2021) Cost efficiency status of rice farmers participating in IFAD/VCD programme in Niger State of Nigeria. Yuzuncu Yil University Journal of Agricultural Science 31: 268-276.
16. Shehu M E, Ndanitsa M A, Ojo A O, Sadiq M S (2019) Effect of international fund for agricultural development-value chain development programme on poverty status of small-scale rice farmers in Niger State of Nigeria. International Journal of Advanced Research in Statistics Management and Finance (IJARSMF) 7: 185-195.
17. Stein C M, Morris N J, Nock N L (2017) Structural equation modeling. Natignal Centre for Biotechnology Information.
18. Sultanbaeva V, Batykova A, Osmonkanov T, Mamatov N, Askaraliev B (2025) Technologies for adaptation of agriculture to climate change in Kyrgyzstan. Scientific Horizons 28: 104-115.
19. Taibat A M, Bello Z A, Musa D B, Shehu U H (2015). Impact of international fund for agricultural development (IFAD)/community based agricultural and rural development programme (CBARDP) on poverty reduction among rural women in Kebbi State, Nigeria. International Journal of Agricultural Extension 3: 7-12.
20. Tsado J H, Mohammed I, Pelemo J J (2023) Effects of IFAD programme on the income of rice producers in Agricultural Zone III of Niger state, Nigeria. Proceedings of the 30th Annual National Congress of the Rural Sociological Association of Nigeria (RUSAN).