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Adoption and Effect of Agricultural Technologies on Welfare of Farmers in North-East Nigeria

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Abstract

Farmers in North-eastern Nigeria were characterized by low yield as a result of poor adoption of improved agricultural technologies. Most studies focused on the socio-economic and institutional drivers of agricultural technologies. However, technological characteristics were less emphasized. This study however considered technological characteristics in addition to socio-economic and institutional factors. Besides, this study further analysed beyond drivers of adoption of agricultural technologies to the effect of adoption of agricultural technologies in broader sense on welfare of farmers and its determinants in North-east Nigeria. Multi-stage sampling method was used to arrive at 600 farmers/participants. Data were collected using questionnaire which were analysed using descriptive statistics, ordered logistic regression and ANOVA. The result revealed that adoption status of agricultural technologies in North-Eastern Nigeria significantly (P≤0.01) varied across category of adopters (adopters, semi-adopters and non-adopters). Adopters' category was higher and statistically differed from semi adopters and non-adopters categories. Sex, age, extension contact, short maturity period, access to credit and high productivity were positively significant (P≤0.01, P≤0.01, P≤0.01, P≤0.05, P≤0.05 and P≤0.1 respectively). Farming experience, farm size, shelf life and fruit size were negative but significant (P≤0.01, P≤0.01, P≤0.01 and P≤0.1 respectively). The adopters were higher in their annual farm income compared to the semi-adopters (P≤0.01) with a total sum of ₦618052.979. Adopters had higher non-farm income than the semi-adopters and non-adopters by ₦207191.740 and ₦103101.420 (P≤0.01 & P≤0.05 respectively). Adopters had higher total annual income than the semi-adopters by ₦825244.719 (P≤0.01). Heterogeneity of farm income, non-farm income and total farm income were not found. It can therefore, be concluded that adoption of agricultural technologies improved farmers' welfare. Hence, it is recommended that livelihood should be improved and strengthened through agricultural innovations; Crops with higher yielding potentials and short maturity should be given priority and Agricultural extension services should be enhanced.

Keywords*: Adoption; Farmers' welfare; North-east Nigeria; Ordered logistic regression*

Adoption Et Effet Des Technologies Agricoles Sur Le Bien-Etre Des Agriculteurs Dans Le Nord-Est Du Nigeria

RESUME

Les agriculteurs du nord-est du Nigéria se caractérisaient par un faible rendement en raison d'une mauvaise adoption des technologies agricoles améliorées. La plupart des études se sont concentrées sur les moteurs socio-économiques et institutionnels des technologies agricoles. Cependant, les caractéristiques technologiques ont été moins soulignées. Cette étude a toutefois pris en compte les caractéristiques technologiques en plus des facteurs socio-économiques et institutionnels. En outre, cette étude a analysé plus en détail, au-delà des moteurs de l'adoption des technologies agricoles, l'effet de l'adoption des technologies agricoles au sens large sur le bien-être des agriculteurs et ses déterminants dans le nord-est du Nigeria. La méthode d'échantillonnage à plusieurs étapes a été utilisée pour arriver à 600 agriculteurs/participants. Les données ont été recueillies à l'aide d'un questionnaire qui a été analysé à l'aide de statistiques descriptives, d'une régression logistique ordonnée et d'une ANOVA. Le résultat a révélé que le statut d'adoption des technologies agricoles dans le nord-est du Nigeria variait de manière significative (P≤0,01) selon la catégorie d'adoptants (adoptants, semi-adoptants et non-adoptants). La catégorie des adoptants était plus élevée et différait statistiquement des catégories des semi-adoptants et des non-adoptants. Le sexe, l'âge, le contact d'extension, la courte période de maturité, l'accès au crédit et la productivité élevée étaient positivement significatifs (P≤0,01, P≤0,01, P≤0,01, P≤0,05, P≤0,05 et P≤0,1 respectivement). L'expérience agricole, la taille de l'exploitation, la durée de conservation et la taille des fruits étaient négatives mais significatives (P≤0,01, P≤0,01, P≤0,01 et P≤0,1 respectivement). Les adoptants avaient un revenu agricole annuel plus élevé que les semi-adoptants (P≤0,01) avec une somme totale de ₦618052,979. Les adoptants avaient un revenu non agricole plus élevé que les semi-adoptants et les non-adoptants de ₦207191.740 et ₦103101.420 (P≤0.01 & P≤0.05 respectivement). Les adoptants avaient un revenu annuel total plus élevé que les semi-adoptants de ₦825244,719 (P≤0,01). L'hétérogénéité du revenu agricole, du revenu non agricole et du revenu agricole total n'a pas été constatée. On peut donc conclure que l'adoption de technologies agricoles a amélioré le bien-être des agriculteurs. Par conséquent, il est recommandé que les moyens de subsistance soient améliorés et renforcés grâce à des innovations agricoles ; Les cultures à haut potentiel de rendement et à courte maturité doivent être prioritaires et les services de vulgarisation agricole doivent être renforcés.

Mots clés : *Adoption ; Bien-être des agriculteurs ; Nord-est du Nigeria ; Régression logistique ordonnée*

اعتماد و تاثير التقنيات الزراعية على رفاهية المزارعين في شمال شرق نيجيريا

نبذة مختصرة

اتسم المزارعون في شم الشرق نيجيريا بإنتاجية من خفضة نتيجة سوء تبنيا لتقنيات الزراعية المحسنة. ركز تم عظم الدراسات على الدوافع الاجتماعية والاقتصادية والمؤسسية للتقنيات الزراعية. ومع ذلك، كانت الخصائص التكنولوجية أقل تأكيدا. لكن هذه الدراسة أخذت في الاعتبار الخصائص التكنولوجية بالإضافة إلى العوامل الاجتماعية والاقتصادية والمؤسسية. إلى جانب ذلك، قامت هذه الدراسة بتحليل أبعد من دوافع تبني التقنيات الزراعية إلى تأثير اعتماد التقنيات الزراعية بمعنى أوسع على رفاهية المزارعين ومحدداته في شمال شرق نيجيريا. تم استخدام طريقة أخذ العينات متعددة

المراحل للوصول إلى *600* مزارع / مشارك. تم جمع البيانات باستخدام الاستبيان الذي تم تحليله باستخدام الإحصاء الوصفي والانحدار اللوجستي المرتبو .*ANOVA* كشفت النتيجة أن حالة تبني التقنيات الزراعية في شمال شرق نيجيريا تباينت بشكل كبير *(P≤0.01)* عبر فئة المتبنين) المتبنين، شبه المتبنين وغير المتبنين (كانت فئة المتبنين أعلى واختلفت إحصائيًا عن الفئات شبه المتبنية وغير المتبنية. كان الجنس والعمر والاتصال الممتد وفترة النضج القصيرة والوصول إلى الائتمان والإنتاجية العالية معنوية إيجابية *(P≤0.01* و *P≤0.01* و *P≤0.05* و *P≤0.05* و *P0.1* على التوالي). كانت تجربة الاستزراع وحجم المزرعة ومدة الصلاحية وحجم الثمار سلبية ولكن معنوية *(P≤0.01* و *P≤0.01* و *P0.1* على التوالي). كان المتبنون أعلى في دخلهم الزراعي السنوي مقارنة بأشباه المتبنين *(P≤0.01)* بإجمالي إجمال يقدره *618052.979* ين . كان لدى المتبنين دخل غير زراعي أعلى من شبه المتبنين وغير المتبنين بمقدار *207191.740* و *P≤0.05 & P≤0.01) 103101.420* على التوالي .(كان لدى المتبنين إجمال يدخل سنوي أعلى من شبه المتبنين بمقدار .*(P≤0.01) 825244.719* ₦ لم يت مال عثور على عدم تجانس دخل المزرعة والدخل غير الزراعي وإجمال يدخل المزرعة. لذلك يمكن استنتاج أن اعتماد التقنيات الزراعية أدى إلى تحسين رفاهية المزارعين .ومنثم، يوصى بضرورة تحسين سبل العيش وتقويتها من خلال الابتكارات الزراعية؛ وينبغي إعطاء الأولوية للمحاصيل ذات الإمكانات العالية الغلة والنضج القصير، كما ينبغي تعزيز خدمات الإرشاد الزراعي.

الكلمات المفتاحية: التبني؛ رفاهية المزارعين؛ شمال شرق نيجيريا؛ الانحدار اللوجستي المطلوب

Introduction

Adoption of Agricultural technologies is influenced by many factors (Streletskaya, Bell, Kecinski, Li, Banerjee, Palm-Forster and Pannell, 2020; and Vecchio, Agnusdei, Miglietta and Capitanio, 2020). Technology adoption has been the key to improving productivity and welfare of farmers (Biru, Zeller and Loos, 2020; Workineh, Tayech and Ehite, 2020; and Olagunju, Ogunniyi, Awotide, Adenuga & Ashagidigbi, 2020). Poverty in Sub-Saharan Africa was decreasing in the poverty headcount rate (from 38.9 to 38.3 between 2018 and 2019), but an increase in the number of people living in poverty, up from 420 million in 2018 to 424 million in 2019 (World bank, 2022).

Agriculturally based rural development is recognized to be vital not just for improving food security but also for assisting livelihoods outcomes, particularly for rural farming households which constitutes about 75% of the world's poor (Alene, 2010; Michler, Baylis, Arends-Kuenning, and Mazvimavi, 2019). However, agricultural technology is driven by socio-economic, institutional, psychological, cultural and technological factors which subsequently translates into improved welfare of the farmers (Mugumaarhahama, Mondo, Cokola, Ndjadi, Mutwedu, Kazamwali, Cirezi, Chuma,Ndeko, Ayagirwe, Civava and Mushagalusa, 2021; Tibamanya, Henningsen and Milanzi, 2022; and Xie and Huang, 2021). Income was used as a measure of welfare as used by many studies; this was because it reflects the heterogeneity of peoples' experiences on their respective welfare (e.g. Aitken, 2019; Avram and Popova, 2022; and Mansoorian, Michelis andAngyridis, 2022).

More than one million families in North East Nigeria are expected to be extremely famished, this includes more than 600,000 fronting severe hunger, who may die if nothing is done (FAO, 2021). In addition, more than 123,000 pregnant/lactating women were also expected to suffer from critical malnutrition due to the impact of insurgency, leading to poor food accessibility, possible outbreaks of acute

diseases; this situation might further be exacerbated by the impact of COVID-19 pandemic on farmers' socio-economics (FAO, 2021). Despite inability of farmers to plant and harvest for up to three sequential farming seasons, speedily kick-starting agricultural production and agricultural livelihoods is critical to reduce hunger and build self-sufficiency (FAO, 2022). North-eastern Nigerian farmers had problems of: farm input quality and dissemination; fair input subsidization; training; market facilitation; corruption; and insecurity (Che, Strang and Vajjhala, 2020).

Studies were conducted to ascertain the drivers of agricultural technologies for instance Mustapha, Man, Shah, Kamarulzaman and Tafida (2022) examined farmers' socioeconomic characteristics, classifies the types of ICT tools adopted by the respondents and identifies factors influencing the adoption of ICT in extension service delivery among the respondents.Gailyson,Haruna and Apollos (2011) analysed a factors influencing farmers' adoption of irrigated rice production in North-eastern Nigeria and also KA, and Offar (2022) focused on studying the factors that influence the adoption of bio-herbicide technology as an alternative to the chemical herbicides used by rural farmers in the North-Eastern of Nigeria. All the studies focused on the drivers of technologies in which technological characteristics were ignored in their studies. This study however considered technological characteristics in addition to socio-economic and institutional factors. Besides, this study further analysed beyond determinants of adoption to the effect of agricultural technology adoption on welfare of farmers and it was not tied to a particular technology.

The study adds to body of literature on technological characteristics drivers of adoption and effect of adoption on welfare of farmers in broader sense.

Material and methods

Study Area

The study was carried out in north-eastern Nigeria which comprises of Adamawa, Borno, Bauchi, Gombe, Taraba and Yobe States. The area is situated between the latitudes of 6º20' to 13º 00' from the north and 9º 00'to 14º 00' east of the Greenwich Meridian.The geo-political zone has a population of 21,549,699 (2016 Census figure) with land area of 241,076 Km^2 .The vegetation of the study area ranges from Sahel Savanna in Yobe and Borno States to the Guinea Savanna in Taraba State (Adebayo and Umar, 1999 in Mustapha, *et. al*. 2022; NPC, 2006).

Sampling Procedure

Three states were purposively selected from the six states. This was due to the security situation in the other states. The states selected were Bauchi, Gombe and Taraba states. Two local government areas were purposively selected from Bauchi and Taraba states while one local government area was purposively selected from Gombe State. This gave a total of five local government areas selected for the study. The selection of two local government areas each from Bauchi and Taraba states and one local government area from Gombe state was in proportion to the number of local government areas in the states. From each of the five local government areas, six villages were purposively selected giving a total of thirty villages used for the study. In each village, twenty farmers were randomly selected, giving a total of six hundred farmers who formed the respondents for the study. List of farming households engaged in

agricultural production for all the villages were obtained from the village extension worker of the respective State Agricultural Development Projects (ADPs). The lists formed the sampling frame from which the sample selection was done.

Method of Data Collection

Primary data were collected using Questionnaire, information such as socio-economic characteristics of farmers, institutional factors and technological characteristics were collected from the farmers.

Method of Data Analysis

Data were analysed using both descriptive and inferential statistics with a help of Statistical Package and Service Solution (SPSS) version 23 and STATA version 13. Descriptive statistics (frequency, percentage, mean and standard deviation) were used to summarize the data. Ordered logistic regression was used to analyse the drivers of adoption of agricultural technologies and Analysis of variance (ANOVA) was used to examine the welfare effect of adoption of agricultural technologies as used by Shehu (2017).

Result and Discussion

Distribution of Respondents Based on Continuous Socio-economic Characteristics

Table 1 showed that the average age of the respondents was 34.96 (11.215) years, this showed that the farmers were in their active Age to engage in farming. The average level of Education was found to be 2.12 (1.023). This revealed that most farmers had at least secondary school education. The average years of Farming experience was 18.88 (11.175), this means that farmers had enough farming experience to make wise decision in regards to their farms. The average farm size was 22.98 (530.67), this depicts large farms for agricultural production. Average annual farm income was found to be ₦876,403.36 (1520417.409), average Annual non-farm income was found to be ₦271,862.50 (430195.927) and Annual income was ₦1,148,265.86 (1762309.87). The average rating of technological characteristics was: High Productivity 9.29 (0.897); Ease of pest and disease control 9.05 (1.196); Short maturity duration 9.18 (0.919); Shelf-life 9.03 (1.058); Level of Profit 9.18 (0.89); and Fruit Size 9.38 (0.859). This showed the high rating of each technological characteristic which proved the desire for each in crops developed for farmers' use. The standard deviations revealed the less dispersion within farmers in all the technological characteristics. Average Adoption status 1.27 (0.81429) this depicts farmers to averagely semi adopters of technology.

Table 1: Distribution of Respondents Based on Continuous Socio-economic Characteristics

Variable	Description	Mean	Std. Deviation
Age	Number of years	34.96	11.215
Level of Education	0= no formal education, 1= primary, 2=secondary, 3= tertiary	2.12	1.023
Years of farming experience (years)	Number of years in farming activities	18.88	11.175
Farm size (Ha)	Number of hectares of land	22.98222	530.671035
Annual farm income (₦)	Amount of farm income in Naira	876403.36	1520417.409
Annual non-farm income (₦)	Amount of non-farm income in Naira	271862.50	430195.927
Annual Income (₦)	Total annual income in Naira	1148265.86	1762309.873
High Productivity	Seed productivity rating in 10 scale	9.29	0.897
Ease of pest and disease control	Seed ease of pest and disease control rating in 10 scale	9.05	1.196
Short maturity duration	Seed short maturity rating in 10 scale	9.18	.919
Shelf-life	Seed shelf life rating in 10 scale	9.03	1.058
Level of Profit	Seed level of profit rating in 10 scale	9.18	.890
Fruit Size	Seed fruit size rating in 10 scale	9.38	0.859
Adoption	Adoption status of the respondents (0= non-adopter, 1= semi-adopter, 2= adopter)	1.27	0.814

Distribution of Respondents Based on Nominal Socio-economic Characteristics

Table 2 revealed that sex of the farmers was majority (86.7%) males, this means males dominated the farming activities in North-east Nigeria. Majority (80%) of farmers reported to had extension contact. This proved the wide spread of extension services in the region. Most (84.8%) did not were not members of any group. Furthermore, majority (67.2%) had accessed to one form a credit in North-eastern Nigeria.

Table 2: Distribution of Respondents Based on Nominal Socio-economic Characteristics

Variable		Frequency	Percentage
Sex	Female	80	13.3
	Male	520	86.7
Total		600	100.0
Extension contact	Not contacted	120	20.0
	Contacted	480	80.0
Total		600	100.0
Group membership	Non-member	509	84.8
	Member	91	15.2
Total		600	100.0
Access to credit	Not accessed	197	32.8
	Accessed	403	67.2
Total		600	100.0

Distribution of Respondents Based on Adoption Status in North-eastern Nigeria

Table 3 showed that the adopters of agricultural technologies in North-eastern Nigeria was significantly (P≤0.01) varied across category of adoption status (adopters, semi-adopters and non-adopters). The result revealed that there was no difference between distribution of semi-adopters and non-adopters across north-eastern Nigeria as shown by the observed frequencies which were lesser than the expected frequency. However, adopter category was higher and statistically differed from semi adopters and non-adopters categories. This showed that majority of north-eastern Nigeria farmers adopted improved agricultural technologies in their production activities. This was possibly due to implementation of various agricultural programmes in the region by government and humanitarian NGOs. Also, it could be due adverse effect of the insurgency in the region on farmers' livelihood that coerced them to looks for more improved agricultural innovations for optimum productivity in their respective farms. This was in line with (FAO, 2021; FAO, 2022) who showed that farmers were deprived of farming in three consecutive years. However, agricultural production in the region is fast bouncing back.

Table 3: Distribution of Respondents by Adoption Status

Adoption Status	**Observed N**	**Expected N**	**Chi square**	**Df**	**Asymp. Sig.**
Non-adopter	139	200.0	80.47	2	0.001
Semi-adopter	158	200.0			
Adopter	303	200.0			

Drivers of Adoption of Agricultural Technologies

Table 4 showed that the Wald chi^2 (df=13) = 117.96 (P≤0.01). This depicts the reliability of the model as also proven by the Log pseudo-likelihood of -104.20. Sex, Age, Extension contact, Short maturity period, Access to credit and High productivity were found to be positively significant (P≤0.01, P≤0.01, P≤0.01,

P≤0.05, P≤0.05 and P≤0.1 respectively). Farming experience, Farm size, Shelf life and Fruit size were negative but significant (P≤0.01, P≤0.01,P≤0.01 and P≤0.1 respectively).

Sex was found to be positively significant (P≤0.01). This is the proportional odds ratio of comparing males to females on adoption status given that the other variables in the model were held constant. However, the odds of the combined categories of adopters and semi-adopters versus non-adopters is 2.2 times higher for males compared to females, given that the other variables were held constant in the model. This was possibly due to the culture of the area that confined most females to economic activities within their household.

Age was positively significant (P≤0.01). The odds ratio was the proportional odds ratio for a one-year increase in Age on Adoption status given that the other variables in the model were held constant. Thus, for a one-year increase in Age, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 1.057 times greater, given that the other variables are held constant in the model. Similarly, for a one-year increase in Age, the odds of the combined adoption and semi-adoption versus non-adoption were 1.057 times greater, given that the other variables were held constant.

Farming experience was found to be negative but significant (P≤0.01). The odds ratio was the proportional odds ratio for a one-year increase in Farming experience on Adoption status given that the other variables in the model were held constant. Thus, for a one-year increase in Farming experience, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 0.944 times greater, given that the other variables are held constant in the model. Equally, for a one-year increase in Farming experience, the odds of the combined adoption and semi-adoption versus non-adoption were 0.944 times greater, given that the other variables were held constant.

Farm size was negative but significant (P≤0.01). The odds ratio was the proportional odds ratio for a one-year increase in Farm size on Adoption status given that the other variables in the model were held constant. Thus, for a one-year increase in Farm size, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 1.00 times greater, given that the other variables are held constant in the model. Likewise, for a one-year increase in Farm size, the odds of the combined adoption and semi-adoption versus non-adoption were 1.00 times greater, given that the other variables were held constant.

Extension contact was positively significant (P≤0.01). The odds ratio was the proportional odds ratio of comparing famers that had extension contact to farmers that didn't received extension contact on adoption status given that the other variables in the model were held constant. However, the odds of the combined categories of adopters and semi-adopters versus non-adopters is 2.063 times higher for contacted farmers compared to non-contacted farmers, given that the other variables were held constant in the model. Likewise, the odds of the combined categories of non-adopters and semi-adopters versus non-adopters is 2.063 times higher for contacted farmers compared to non-contacted farmers, given that the other variables were held constant in the model. This was possibly due to the extension services creates an awareness and showed the good aspect of the technology beyond any reasonable doubt.

Access to credit was positively significant (P≤0.01). The odds ratio was the proportional odds ratio of comparing famers that had access to credit facility to farmers that didn't had access to credit facility on adoption their status given that the other variables in the model were held constant. However, the odds of the combined categories of adopters and semi-adopters versus non-adopters is 1.499 times higher for farmers that had accessed credit compared to farmers that had not accessed credit, given that the other variables were held constant in the model. Likewise, the odds of the combined categories of non-adopters and semi-adopters versus non-adopters is 1.499 times higher for farmers that had accessed credit compared to those had not accessed credit, given that the other variables were held constant in the model.

High productivity of the technology was positively significant (P≤0.1). The odds ratio was the proportional odds ratio for a one increase in High productivity on Adoption status given that the other variables in the model were held constant. Thus, for a one increase in High productivity, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 1.232 times greater, given that the other variables are held constant in the model. Similarly, for a one increase in High productivity, the odds of the combined adoption and semi-adoption versus non-adoption were 1.232 times greater, given that the other variables were held constant. This is contrary to *Apriori* expectation.

Short maturity of the technology was positively significant (P≤0.05). The odds ratio was the proportional odds ratio for a one increase in Short maturity on Adoption status given that the other variables in the model were held constant. Thus, for a one increase in Short maturity, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 1.308 times greater, given that the other variables are held constant in the model. Similarly, for a one increase in Short maturity, the odds of the combined adoption and semi-adoption versus non-adoption were 1.308 times greater, given that the other variables were held constant.

Shelf life of the technology was positively significant (P≤0.01). The odds ratio was the proportional odds ratio for a one increase in Shelf life on Adoption status given that the other variables in the model were held constant. Thus, for a one increase in Shelf life, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 0.74 times greater, given that the other variables are held constant in the model. Similarly, for a one increase in Shelf life, the odds of the combined adoption and semi-adoption versus non-adoption were 0.74 times greater, given that the other variables were held constant.

Fruit size of the technology was positively significant (P≤0.1). The odds ratio was the proportional odds ratio for a one increase in fruit size on Adoption status given that the other variables in the model were held constant. Thus, for a one increase in Fruit size, the odds of being in adopters' category versus the combined semi-adopters and non-adopters are 0.802 times greater, given that the other variables are held constant in the model. Equally, for a one increase in Fruit size, the odds of the combined adoption and semi-adoption versus non-adoption were 0.802 times greater, given that the other variables were held constant.

Table 4: Factors Influencing Adoption of Agricultural Technologies

Variable	Odds Ratio	Z-value
Sex	2.200 (0.524)	3.31***
Age	1.057 (0.013)	4.46***
Farming experience	0.944 (0.012)	-4.53***
Farm size	1.000 (0.000)	-4.75***
Annual farm income	1.000 (0.000)	-0.78
Extension contact	2.063 (0.390)	3.83***
Group membership	0.889 (0.197)	-0.53
Access to credit facilities	1.499 (0.294)	2.07**
High Productivity	1.232 (0.136)	1.88*
Ease of pest and disease control	1.056 (0.098)	0.59
Short maturity period	1.308 (0.161)	2.19**
Shelf life	0.740 (0.082)	-2.72***
Fruit Size	0.802 (0.092)	-1.92*
Log pseudo-likelihood	-104.20	
Wald chi^2 (13)	117.96	
Prob> chi^2	0.001	
Pseudo R^2	0.064	
Cut1	1.018 (1.45)	
Cut 2	2.29 (1.45)	

Effect of Adoption of Agricultural Technologies on Welfare of Farmers

Table 5 showed that the F-value of the model was 7.53 and significant (P≤0.01), this proved the reliability of the model. In addition, variation was found between the categories of adoption on their annual farm income. The adopters were found to be higher in their annual farm income compared to the semi-adopters (P≤0.01) with a total sum of ₦618052.979 which had a standard error of 174913.312. The standard error revealed that there was no much variation of Annual farm income within the adopters and also within the semi-adopters categories. This was possibly due to improved agricultural technologies, improved yield and quality of the products which was subsequently sold with premium and translates into increased earning. This is in conformity with Murtala, et al. (2021) who found that Adoption of Purdue improved cowpea storage method had impact on farmers' economic status.

In the farmers' Annual non-farm income, adopters had higher Non-farm income than the semi-adopters and non-adopters by ₦207191.740 and ₦103101.420 (P≤0.01 & P≤0.05 respectively) bearing a standard deviation of 49386.773 and 43506.164 respectively. This showed that adoption of agricultural technologies improved non-farm income also with a less variation of Non-farm income within the categories as shown by the standard deviation. Furthermore, semi-adopters had lower non-farm income than the non-adopters with a difference of ₦104090.320 with also less variation within the categories as proved by the standard deviation of 41674.367. This is also in conformity with Murtala, *et al.* (2021) who found that Adoption of Purdue improved cowpea storage method had impact on farmers' economic activities of farmers.

For the Total annual income, adopters had higher Total annual income than the semi-adopters by ₦825244.719 (P≤0.01) with a standard deviation of 202134.828 which depict a less variation within the categories. This was possibly due to improved technologies which had bearing on the livelihood of the farmers. Non-adopters had higher Total annual income than the semi-adopters by ₦590,265.677 (P≤0.01) with lower variation within the categories as depicts by the standard deviation of 170568.753. This might be due to less concentration on a particular variety so as to give it required management practices by semi-adopters. Murtala, *et. al*. (2021) found that Adoption of Purdue improved cowpea storage method had impact on farmers' economic activities. Also, it was in agreement with Oyetunde-Usman, et al. (2021) who found that adoption of DTMVs and organic manure can enhance agricultural productivity and welfare for smallholder farmers in Nigeria.

Table 5: Effect of Adoption of Agricultural Technologies on Income of Farmers

Variable			Mean Difference (I-J)	Std. Error	Sig.	F-value
Annual farm income (₦)	Adopter	Semi-adopters	618052.979*	174913.312	.000	7.53***3
		Non-adopter	131877.623	154085.936	.392	
	Semi-adopters	Adopter	-618052.979*	174913.312	.000	
		Non-adopter	-486175.356*	147598.243	.001	
	Non-adopter	Adopter	-131877.623	154085.936	.392	
		Semi-adopters	486175.356*	147598.243	.001	
Annual non-farm income (₦)	Adopter	Semi-adopters	207191.740*	49386.773	.000	
		Non-adopter	103101.420*	43506.164	.018	
	Semi-adopters	Adopter	-207191.740*	49386.773	.000	
		Non-adopter	-104090.320*	41674.363	.013	
	Non-adopter	Adopter	-103101.420*	43506.164	.018	
		Semi-adopters	104090.320*	41674.363	.013	
Total annual income (₦)	Adopter	Semi-adopters	825244.719*	202134.828	.000	
		Non-adopter	234979.043	178066.117	.187	
	Semi-adopters	Adopter	-825244.719*	202134.828	.000	
		Non-adopter	-590265.677*	170568.753	.001	
	Non-adopter	Adopter	-234979.043	178066.117	.187	
		Semi-adopters	590265.677*	170568.753	.001	

Conclusion and recommendation

From the findings of the study it can be concluded that adoption of Agricultural technologies improved farmers' welfare by ₦618,052.98 through their farm income. These technologies were driven by socio-economic, institutional and technological characteristics. It is therefore recommended that:

(i) livelihood should be improved and strengthened through agricultural innovations in North-east Nigeria;

(ii) Crops with higher yielding potentials and short maturity should be given priority in North-East Nigeria; and

(iii) Agricultural extension services should be enhanced in North-east Nigeria.

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