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Mobile Agricultural Information and Climate Change Adaptation Strategies: Insight from Smallholder Farmers in Kwara, Nigeria

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Abstract- Making key information on agricultural practices available to farmers on mobile phones is important in lessening the impact of climate change. This study, therefore, examined the nexus between agricultural information received on mobile phones and climate change mitigation techniques adopted by smallholder farmers in Kwara State, Nigeria. Employing a multi-stage sampling procedure, 200 respondents were selected and a structured questionnaire was utilized to collect information from them. Descriptive statistics and a multivariate probit model were employed to analyse the socioeconomic characteristics and the nexus between mobile phone information and adaptation to climate change methods, respectively. The result showed that 78% of the respondents were male and the average age was 48 years. About 78% were married and the mean family size was 6. The mean years of formal education is 9 years and the farmers have an average of 13 years of farming experience. Around 20% accessed agricultural information on their mobile phones. Additionally, the climate adaptations adopted by the farmers are early planting (32%), irrigation (31%), multiple planting (11.5%), and mixed cropping (10%). The regression result showed that information received on mobile phones has a significant effect on the adoption of all the climate change adaptation strategies. The study recommends that agricultural climate policies should focus on developing mobile-based agricultural advisory services that are easily accessible to farmers

Keywords- Agricultural information; mobile phone; climate adaptation strategies; Kwara state.

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I. INTRODUCTION

Nigeria's economy depends largely on agriculture, which also accounts for a significant share of the country's GDP [1]. The sector is predominantly driven by smallholders who farm below five hectares of land and bank on rain-fed farming, making them extremely vulnerable to climate change [2]. Irregular rainfall patterns, escalating temperatures, flooding, and intense weather conditions increasingly threaten agricultural productivity and food security [3]. Higher temperatures accelerate pest infestations, reduce soil enzymatic activity, and shorten crop growth cycles [4], while heat stress and soil moisture depletion further undermine yields [5]. In the absence of proactive climate action, Nigerian temperatures are projected to rise by 4°C in 2100 [6] and exacerbate agricultural risks endangering the livelihood of millions who survive on agriculture.

Adaptation to climate change has become an essential part of maintaining agricultural livelihoods. Various methods are adopted by farmers, including delayed planting dates, early planting, intercropping, reduced tillage, and irrigation, among others [1,7,8]. These adaptations, though able to reduce risk, rely on access to timely and quality information. Information and communication technology (ICT), especially mobile phone technology, has become revolutionary tools that provide unprecedented connectivity even in rural settings [9,10]. Increased investment in African ICT infrastructure has made mobile phones cheaper, placing them within reach of even the poorest communities on the continent [11]. Mobile phones thus offer a gateway for farmers to access agrometeorological information, market information, and advisory services that enhance decision-making [12,13].

Incorporating ICT in agriculture bridges knowledge gaps and promotes best agronomic practices, thereby enhancing climate resilient agriculture. Empirical evidence highlights the role of ICT in increasing climate resilience. Studies indicate that Nigerian farmers use mobile technology to obtain real-time weather forecasts, market prices, and agronomic advice [14, 15], reinforcing its potential as a driver of agricultural development. Furthermore, [16, 17, 18] findings indicate that mobile agricultural information positively affects the adoption of fertilizers, improved seed varieties, and market participation. In addition, research has examined the role of mobile technology in upscaling market access, input use, productivity and efficiency [19, 20, 21, 22]. However, these studies have largely overlooked the direct effect of agricultural information received through mobile phones on the adoption of climate change adaptation strategies, leaving a critical gap in the literature.

The extent to which mobile agricultural information aids the successful uptake of adaptation techniques to climate change remains an open question. This study advances the discourse by examining the link between mobile agricultural information and farmers' adaptive behaviors in Kwara State by analyzing how smallholder farmers leverage mobile phones to access climate-related information and implement adaptation strategies. Addressing this gap, our study draws on a sample of 200 smallholder farmers in Kwara State, identifying mobile phone users and assessing their access to climate-related information. Evaluating the factors that drive mobile-enabled climate change adaptation strategies will shed light on the benefits of mobile agricultural information in enhancing agricultural resilience in Nigeria. This provides empirical insights that can inform policy interventions enhancing digital solutions tailored towards addressing the climate change quagmire.

II. METHODOLOGY

A. Area of study

The study was carried out in Kwara State, Nigeria. The state comprises 16 local government areas and spans approximately 32,500 square kilometers. The 2006 census estimated the state population to be around 2.4 million and with an annual growth rate of 3.2%, the number is expected to have increased to over 3 million since 2021[23]. Kwara State's climate favours the growth of tall grasses with scattered short trees, which is a feature of savanna vegetation. Numerous crops, including food crops (yams, cowpeas, maize, cassava) and tree crops (cashew, mango, oil palm), thrive on this vegetation. The climate of the state is tropically wet and dry, with two distinct seasons. The mean annual rainfall is between 1000 to 1500 mm, while the average temperature during the wet season is between 25°C and 30°C. Temperature ranges from 33°C to 34°C during the dry season. The relative humidity ranges from 75% to 80% during the rainy season and roughly 65% during the dry season.

B. Sampling Techniques and Sample Size

A three-stage sampling technique was utilized in this research. Zones C and D were purposefully chosen among the state's four Agricultural Development Programme (ADP) zones in the first stage. These zones were specifically chosen due to their relatively advanced ICT infrastructure compared to other zones, as well as their higher concentration of farmers. In the second stage, two local government areas (Asa and Ilorin East) and four local government areas (Ekiti, Irepodun, Offa, and Oyun) were chosen at random from Zones C and D, respectively. In the final stage, a random sample of 35 farmers was selected from each local government area, yielding a total of 210 respondents. However, only 200 questionnaires were deemed valid for analysis due to missing key variables in the remaining responses.

C. Types of Data and Method of Data Collection

This study banked on primary data to actualise its objectives. Kobo toolbox digital data collection platform was adopted for data collection. This platform enabled the researchers to create structured questions on the socioeconomic characteristics, mobile agricultural information, and climate mitigation methods employed by the farmers. The platform is remotely accessible and data may be collected via mobile devices like smartphones or tablets. Kobo toolbox makes it possible to capture the GPS of data collection points, which may then be utilized to make maps and examine spatial trends to guarantee the accuracy and consistency of the data gathered across the research region.

D. Analytical Techniques

Mean, frequency, and percentages (descriptive statistics) were used to describe and summarize data on socioeconomic characteristics, mobile agricultural information, and Farmers' adoption of climate adaptation measures. The influence of mobile agricultural information on Farmers' adoption of climate adaptation measures was analysed with multivariate probit regression.

E. Multivariate Probit Regression

The multivariate probit regression model specified in equation (1) is defined by a set of 'j' binary response factors Y_{jj}

$$Y_{ij}^{*} = X_i\beta_j + U_i \quad (1)$$

where X_i is a vector of factors that explain Y_{jj}, Y_{ij}^{*} constitutes the climate change adaptation strategies employed by the farmers which range from 1 – 4 in this study. There are multiple planting dates, early planting, irrigation and mixed cropping respectively. β_j is the vector coefficient to be estimated and U_i *is* the error term. Using any strategy is simply a binary option for each method, this is represented in equation (2)

$$Y_j = \begin{cases} 1 \; if \; Y_{ij}^{*} > 0 \\ 0 \; otherwise \end{cases} \quad (2)$$

The underlying assumption is that U_i in equation (1) jointly uphold a multivariate normal distribution with a mean and variance equal to zero and one, respectively, because it is feasible to choose many adaptation strategies. Because of this assumption, equation (2) provides a model that jointly depicts a choice to employ each mitigation measure.

III. RESULTS AND DISCUSSIONS

A. Socio-economic characteristics of the farmers

The description of the socioeconomic characteristics is shown in Table 1. The result showed that 78% of the farmers are male, reinforcing their dominance in agricultural production. This is probably due to the tedious nature of agriculture, moreover, males have more access to agricultural production resources. The result is confirmed by [24, 25], who observed in their studies that males dominate agricultural production in Nigeria. The average age of the farmers is 48 years, this means that farmers in the Kwara state are relatively young and still within the active working population in Nigeria. This also suggests that farmers in this research area will be experimental and utilise ICT tools, which will help them embrace climate change mitigation measures. This finding is consistent with [26], who observed that the average age of farmers in Kwara state is 48 years.

According to the results in Table 1, 78% of farmers are married and the family size is 6. This means that the farmers have individuals who depend on them for provisions. This makes them committed to economic activities to fend for their families. This finding is confirmed by [27], who posited that married people are more involved in agriculture. Furthermore, the relatively large family size serves as labour in the absence of hired labourers. The mean years of formal education is approximately 9. This suggests that the majority of farmers have basic formal education. Access to education has a positive influence on the knowledge, perception, and attitude of farmers. Educated farmers comprehend climate change issues better and adapt promptly. According to [28], farmers with one form of education or the other would likely implement techniques that aid climate change management.

The mean farm size of about 2 hectares suggests that most of the farmers are smallholders; this will likely make them vulnerablele to climate-related risks. According to [29], farmers with large farm sizes are less vulnerable to climate change risks. The average farming experience was 13 years, indicating that most farmers have invested a significant number of years into agriculture. This implies that they probably have encountered various climate change challenges, making them familiar with its dynamics. Their experience equips them with the knowledge to make intelligent choices concerning climate change mitigation techniques suited to their specific conditions. This corroborates the result of [30] that a rise in the farmer's years of experience will lead to an increased ability to overcome climate challenges.

About 51% of the farmers belong to farmer associations. This suggests that about half of the farmers will likely have access to information, support, networking opportunities, and resources. Farmers in this category would better adapt to climate change than their counterparts who do not belong to any association. About 42% have access to services offered by extension agents, this reveals a vital gap in the delivery of extension services. It follows that farmers with extension contact may differ from those without access regarding adaptation to climate change. According to [31], the adoption of climate change management strategies may be impeded by the lack of adequate extension agents.

The mean credit accessed is ₦119575 ($78); this is relatively small and suggests that many of the farmers do not have access to sufficient credit to adopt climate-resilient farming practices [32] opined that farmers who do not have access to finances may not be able to manage farm risks effectively, therefore resulting in low productivity and food insecurity. About 20% of the farmers used mobile phones to access climate-related information, this implies that the majority of the farmers do not use their mobile phones to access climate-related information. This needs to be worked on as real-time climate-related information can be assessed on one's mobile phone on the go, which will aid effective climate change adaptation.

TABLE 1: SOCIO-ECONOMIC CHARACTERISTICS OF THE FARMERS

Variables	Description of the variables	Mean	Std.dev
Sex	If the respondent is male, 1; if not, 0	0.78	0.42
Age	Age of the farmers in years	48.13	11.00
Marital status	If the respondent is married, 1; if not, 0	0.78	0.42
Family size	The number of family members	6.10	2.92
Formal education	Years of formal education of the farmer	8.65	4.85
Farm size	The size of the farm in hectares	2.26	1.05
Farming experience	Years of experience in farming	12.73	8.66
Members of association	if the respondent belongs to a farmers' association, 1; if not, 0	0.51	0.50
Extension contact	1 if the respondent has access to extension service, 1; if not, 0	0.42	0.49
Credit received	Credit received in (₦)	119575	199767.3
Mobile agric.info	if the respondent received mobile agricultural information, 1; if not, 0	0.20	0.40

B. Climate change adaptation strategies employed by farmers through mobile agricultural information.

The result of climate change adaptation strategies employed by farmers through information received on their mobile phones is presented in Table 2. There are four climate change adaptation strategies employed by the farmers. These strategies include multiple planting dates, early planting, irrigation, and mixed cropping. Early planting (32%) is the most employed measure, closely followed by irrigation (31%). Planting early helps to avoid late-season droughts, and it improves crop yields in areas where erratic rainfall is prevalent.

Approximately 12% of farmers banked on multiple planting dates to adapt to the vagaries of climatic events, while mixed cropping is the least adaptation strategy utilised by the farmers. Planting at different dates helps farmers hedge against sudden weather changes. This strategy ensures that some of the crop planted at different dates attains maturity if there are climatic shocks; this helps reduce risks associated with climate change. However, the lower adoption rate may be due to logistical challenges, such as labour constraints and seed availability. Mixed cropping increases resilience by improving biodiversity and soil health. Its adoption rate is relatively low, possibly due to preferences for monocropping and the need for specialized knowledge. Knowledge of mixed cropping benefits and encouraging multiple dates should be made available to the farmers.

TABLE 2: CLIMATE CHANGE ADAPTATION STRATEGIES EMPLOYED BY FARMERS THROUGH MOBILE AGRICULTURAL INFORMATION.

Response strategies	No. of farmers	% of the farmers
Multiple planting dates	23	11.50
Early planting	64	32.00
Irrigation	62	31.00
Mixed Cropping	20	10.00

C. Effect of Mobile Agricultural Information on Climate Change Adaptation Strategies

The effect of mobile agricultural information on climate change adaptation strategies in Table 3 offers critical insights into how information received on mobile phones and socioeconomic factors influence the adoption of adaptation techniques to climate change. The four adaptation measures analysed are multiple planting dates, early planting, irrigation, and mixed cropping**.** The model fits the data, as indicated by the Wald chi2 = 221.9, Prob > chi2=0.000, and Log-likelihood = -240.81023. According to the figures, the explanatory variables significantly affect the dependent variables as they jointly explain variations in the response variables.

The result revealed that sex is negative and significant with the adoption of mixed cropping as a mitigation strategy for climate change. This implies that female farmers will be more inclined to adopt this measure to counter the plague of climate change compared to men. This can be attributed to risk aversion by women, concern for food security, and limited land access. This finding is supported by [33, 34], who hypothesized in their study that women farmers are more likely to embrace mixed cropping as a buffer against climate change. Age has a positive impact on the adoption of multiple planting dates, meaning that older farmers adopt this activity in addressing the threat of climate change more than younger farmers. Age negatively influences early planting, irrigation, and mixed cropping, implying that older farmers are less likely to adopt these strategies compared to younger farmers. This trend is explained by the innovativeness and experimentality of adopting new agricultural practices among young farmers. These findings are consistent with the arguments of [8,35,36], who asserted that young farmers are more prone to adopt climate-resilient practices.

The family size has a negative effect on mixed cropping adoption, such that it may limit large families financially, preventing them from having the ability to adopt diversification activities. This is similar to the findings of [37, 38], which suggested that family size has a negative impact on climate adaptation strategies implementation. Farm size positively affects the practice of mixed cropping and shows that individuals with large farm sizes have greater flexibility to implement diversification strategies. Additionally, farm experience positively affects early planting, irrigation practice, and mixed cropping systems. This highlights the fact that experienced farmers implement traditional knowledge and mixed cropping strategies as risk-coping mechanisms. This evidence supports the observation of [36], which asserted that farming experience is likely to increase the adoption of climate adaptation measures. Membership in an association is positively related to the practice of mixed cropping, emphasizing the role of collective action in facilitating knowledge exchange and access to resources. Contact with extension services has a positive impact on multiple planting dates, suggesting that extension services enhance the ability of farmers to adopt multiple planting dates according to climate forecasts. These results emphasize the necessity to enhance agricultural extension services and farmers' organizations as avenues for knowledge transfer and climate resilience. According to [35, 39] access to extension services significantly supports the practicing climate adaptation strategies. Further, credit received has a positive impact on all adaptation methods. This underscores the important function of financial assets in facilitating climate adaptation. Credit access allows farmers to buy improved farm inputs (irrigation equipment, hired labour, improved seeds, etc.), thereby reducing their vulnerability to climate-related shocks. Ref [40] has also reported similar results, where credit received enhances farmers' ability to adopt climate mitigation measures. Mobile agricultural information has a direct positive impact across all four measures of adaptation, indicating that the availability of information via mobile phones facilitates farmers' utilization of various forms of adaptation. The finding corroborates the notion that mobile phones are major facilitators of access to information, enabling farmers to obtain agriculture-related information that cushions the impact of climate-related perturbations. These findings align with [41], who confirmed that mobile phones support information flow, leading to better climate management decisions.

TABLE 3: EFFECT OF MOBILE AGRICULTURAL INFORMATION ON CLIMATE CHANGE ADAPTATION STRATEGIES

Variables	Multiple planting dates Coeff. (S.E)	Early planting Coeff. (S.E)	Irrigation Coeff. (S.E)	Mixed Cropping Coeff. (S.E)
Sex	-.18201 (.3587)	.3372 (.2721)	.1392 (.2346)	-.5824* (.3466)
Age	.03965*** (.0150)	-.0452*** (.0149)	-.0465*** (.0158)	-.0387** (.0157)
Marital status	.4326 (.4075)	-.1750 (.2606)	-.1725 (.2579)	.3303 (.3541)
Family size	-.0678 (.0656)	-.0053 (.0576)	-.0069 (.0489)	-.1364* (.0825)
Formal education	-.0119 (.0297)	.0181 (.0251)	-.0148 (.0253)	-.0234 (.0331)
Farm size	-.0592 (.1206)	.0926 (.1430)	.1389 (.1279)	.3211** (.1283)
Farming experience	-.0205 (0239)	.0707*** (.0230)	.0371* (.0198)	.0511** (.0256)
Association membership	.2388 (.3072)	-.2730 (.2766)	.0790 (.2426)	1.0347*** (.3778)
Extension contact	.4483* (.2637)	.3564 (.2391)	.10098 (.2480)	.3037 (.2803)
credit received	2.1e-06*** (6.8e-07)	2.2e-06** (1.1e-06)	1.9e-06** (9.4e-07)	1.5e-06** (7.6e-07)
Mobile agricultural information	1.3340*** (.32579)	.6743*** (.2505)	1.2269*** (.2667)	.8779*** (.323)
Number of observations = 200; Wald chi2 = 221.97; Prob > chi2=0.000; Log-likelihood = -240.81023				

Robust standard errors are in parentheses
***, ** and * are significant at 1%, 5% and 10% respectively

IV. CONCLUSION

The study assessed the nexus between mobile agricultural information and climate change adaptation strategies. The result revealed that 78% of the farmers were male and the average age was 48 years. The mean family size was 6 while the average years of formal education was 9. About 20% accessed agricultural information on their mobile phones. Furthermore, the climate adaptations adopted by the farmers are early planting, irrigation, multiple planting and mixed cropping (10%). Additionally, the information received on mobile phones has a significant effect on the adoption of all the climate change adaptation strategies. Also, factors like sex, age, farm size, and family size credits, extension service, and farmers' association membership influence specific adaptation choices. The study recommends that agricultural climate policies should focus on developing mobile-based agricultural advisory services that are easily accessible to farmers. Governments should promote low-interest agricultural loans and microfinance schemes tailored to smallholder farmers, improve agricultural extension services, encourage farmer cooperatives and empower female farmers through targeted training programs and access to land and credit.

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