

# A Web-Based Mobile System for Promoting Agribusiness in Northern Nigeria

I. M. Mungadi, M. S. Argungu, N. I. Mahmud

**Abstract**—This research aimed at developing a web-based mobile system and figuring out a better understanding of how could “web-based mobile system supports farmers in Kebbi State”. Thus, by finding out the answers to the research questions, a conceptual framework of the entire system was implemented using Unified Modelling Language (UML). The work involved a review of existing research on web-based mobile technology for farmers in some countries and other geographical areas within Nigeria. This research explored how farmers in Northern Nigeria, especially in Kebbi state, make use of the web-based mobile system for agribusiness. Also, the benefits of using web-based mobile systems and the challenges farmers face using such systems were examined. Considering the dynamic nature of theory of information and communication technology; this research employed survey and focus group discussion (FGD) methods. Stratified, random, purposive, and convenience sampling techniques were adopted to select the sample. A questionnaire and FGD guide were used to collect data. The survey finds that most of the Kebbi state farms use their alternative medium to get relevant information for their agribusiness. Also, the research reveals that using a web-based mobile system can benefit farmers significantly. Finally, the study has successfully developed and implemented the proposed system using mobile technology in addition to the framework design.

**Keywords**—Agribusiness, farmers, Kebbi State, mobile technology, Northern Nigeria, web-based.

## I. INTRODUCTION

AGRICULTURE played an important role in the development of technology and economic development, almost 80% of the population [2] of a developed country is engaged in agriculture and agricultural-related activities. Agribusiness like the production of cotton, rice, cocoa, groundnut, cassava, sorghum, and oil palm accord a lot to foreign exchange earnings for Nigeria [2]. This shows that agriculture has played and continues to play an important role in history as well as the development of Nigeria.

The review of agricultural contribution to Gross Domestic Product concern as of 1st quarter 2020 is about 22%. In Nigeria, the agricultural sector was and remains the largest employer, 36% of the labor force was employed in the agricultural sector [3]. This shows that only about N40 billion was earmarked by the government for agricultural research and development (R&D) in 2019. In Nigeria, almost 80% population are farmers and Small Holder Farmers. These numbers accommodated 90% of Nigeria's agricultural produce. The budget in Nigeria in 2020

for agriculture shows 1.8% (or N183 billion) of the total 2020 budget size. While the budget which was proposed for 2022 agricultural and rural development represents 291.4B. Nigerians spent a lot of money on foodstuff, which presents about N22.8 trillion on food items, thereby showing the current state of agriculture in Nigeria [3].

The remaining aspect of agricultural business activities range from the harvesting of farm produce, the transition of farm produce (i.e. maize, cassava, and others) or farm products (i.e. a cow, fish, tomatoes, and the likes), driving from the farm or rural areas to the market places within the country or urban areas for selling, storing and preserving of these products. The above-mentioned related activities are considered major sources of income for Nigerians and serve as a livelihood for both the urban and the rural areas of the country [1].

If farmers can adopt and engage in using a web-based mobile system it can assist them to search for information quickly and lower the transaction cost which in addition enables greater participation of farmers in agribusiness-related activities. It is essential to know the economic impact of web-based mobile system technology in promoting agribusiness in the field of agriculture and rural development [4].

## II. METHODOLOGY

### A. Research Design

We use a survey research method, UML Software, PHP, HTML, MySQL, JS, and wamp server. The survey research method is found to be most appropriate for a study of this nature. This study aims to design and implement the web-based mobile system and know the impact of the web-based mobile system in promoting agribusiness among Kebbi farmers. Survey research studies both large and small populations by a selection of the sample, chosen from the population to discover vital facts from people on their beliefs, opinion, and attitudes. The questionnaire is employed because the population to be studied is large to be observed directly. It is also a suitable method to use to collect a vast number of data because it makes data arrangement and computation easy. UML Software is also found to be most appropriate to design the framework of the web-based mobile system, and PHP, HTML, MySQL, JS, and wamp servers, are more suitable for designing web application systems.

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### B. Area of the Study

As indicated by the project title the area of this research study is in Kebbi state. Therefore, proper attention will be paid to the distribution of questionnaires in the four Emirates by selecting some local government areas, within Kebbi state.

### C. The Population of the Study

The total population in this research is farmers of Kebbi state. Kebbi state is one the major parts of this country that produce more paddy and sack rice to many parts of this country. The Kebbi State has more than 70,000 farmers participating currently in the Anchor Borrowers Rice and Wheat farming, and this makes Kebbi heading towards a new destination and hub for agro-based commodities of the country [6].

### D. Sample Techniques/Sample Size

The sampling technique used in this study is the Stratified Random Sampling technique [7].

In Kebbi, there are 4 emirates comprising 21 local governments that make up the state: Gwandu, Argungu, Yauri and Zuru the emirate. The local governments are: Aleiro, Arewa Dandi, Argungu, Augie, Bagudo, Birnin Kebbi, Bunza, Dandi, Fakai, Gwandu, Jega, Kalgo, Koko/Besse, Maiyama, Ngaski, Sakaba, Shanga, Suru, Wasagu, Yauri and Zuru.

Using Stratified Random Sampling out of these 21 local governments 4 will be strata selected for this study. These four local governments will be selected because they are the largest local governments in Kebbi and they harbor more farmers who can provide answers to the questions raised [6]. These local governments are Gwandu, Argungu, Yauri and Zuru, the study will only focus on those at the age of 21 and above, because the study is dealing with adults. Therefore, with regard to the questionnaire 320 adult will be chosen for this study.

We will visit each of the villages from one household to another in the early hour and evening when the farmers go or come back from their farms and distribute the questionnaire to each farmer found in these villages. This is done to give every farmer in the sample an equal opportunity of being chosen as a respondent.

### E. Instrument for Data Collection

The research instrument used in data collection was a questionnaire. The questionnaire contained 20 close-ended questions drawn and administered to 320 respondents in the four local governments.

The research instrument was divided into two parts. Part one concerned with personal data and items such as age, marital status, and educational qualification, while part two will contain general information items relating to the study.

The questionnaire was administered by the researcher, project supervisor, and the chief farmers. The questionnaires will be completed and collected from the 320 respondents.

### F. Method of Data Collection

The primary and secondary sources will be employed in collecting data for the study. The questionnaire represented the primary source of the data, while library materials, internet materials, interviews, journals, and textbooks formed the

secondary sources.

### G. Method of Data Analysis

All data collected are analyzed using simple percentages of frequencies concerning questions asked.

Responses of farmers are carefully collected and tabulated. The percentages are analyzed based on the tabulated responses of the individual farmers.

The main technique employed to analyze data was the use of chi-square ( $X^2$ ). It is a measure of discrepancy existing between the observed frequencies and the expected frequencies of one, two, or more variables. Chi-square is frequently used in testing hypotheses concerning the differences between the asset of observed frequencies of a sample and the corresponding set of expected frequencies [8].

The formula for finding chi-square ( $X^2$ ) is statistically stated [8]:

$$x^2 = \sum \frac{(o_i - e_i)^2}{e_i} \quad (1)$$

where  $X^2$  = Chi-square;  $O_i$  = Observed frequency;  $E_i$  = Expected frequency;  $\sum$  = Summation.

The Chi-square was used to analyze result from respondents.

Decision: The analyzed result from Chi-square ( $X^2$ ) test of independence is to validate the statistical hypothesis at a 5% level of significance to drive a decision.

Decision Rule: - Reject the Null hypothesis ( $H_0$ ) if the calculated frequency is greater than the tabulated, otherwise accept [8].

## III. RESEARCH MOTIVATION

Many kinds of research were conducted in different parts of the world, In Africa and Nigeria, on a web-based application system. In the southwest part of Nigeria, similar research was conducted on the impact of mobile phones on agribusiness by farmers in the southwest, the study had investigated the current situation in terms of how farmers in southwest Nigeria employed the web-based mobile system for agribusiness, the impact of mobile phone use on farmers agricultural activities and the challenges that confronted farmers as they used mobile to drive their farming business [9]. Because northwest especially Kebbi State is one of the major parts of Nigeria that engage in agribusiness activities it was observed that Kebbi is a more industrialized state compared to a previous time when the Governor of Kebbi state found it before the transformation [6].

Does the web-based mobile system have an economic (negative and positive) impact on promoting agribusiness to farmers in the Northwest, especially in Kebbi State? This question forms part of the strong motivating factors for the research. It is very essential to know the benefit of using web-based mobile system and challenges farmers face using the system.

## IV. LITERATURE

The impact of the web-based mobile system in promoting

agribusiness cannot be over-emphasized especially for farmers living in rural areas of any country. Most of the developing countries' population depend on agricultural business activities. Therefore, it is a good idea to enhance the living standard quality of farmers usually living in rural areas of developing countries. This can be achieved only by increasing their farming productivities, which includes having a good market for their products for them to gain much profit which can probably uplift their income and take away the poverty. Therefore, it is necessary to assist the farmers living in rural areas of such countries [10].

A review attempts to figure out the awareness regarding behavior, intention and the benefit of mobile phones for agriculture, marketing and weather information regarding the farmers living in Sindh, Pakistan. The research uses the quantitative method for the collection of data from 1500 farmers from ten districts of Sindh. The finding reveals that farmers use mobile phones more than 97% on the other hand 23.3% of the respondents use the internet on their mobile phones to get different information. The research, however, finds that the benefit of information and technology cannot be over-emphasized in the society due to its significance in changing the lives of common men and society as well. Farmers have played an important role in the development of technology but most of the farmers. In addition to this, a farmer in Sindh does not properly adopt the use of a mobile phone to connect to the market and get the relevant information. However, after the research was conducted majority of the farmers agreed to use a mobile phone in the future for agricultural information [11].

An approach tried to provide the mobile-based extension service for agribusiness related activities. The literature review attempts to figure out the quality of agricultural extension messages between private and public providers. The research uses a questionnaire for the collection of data from 120 farmers as a sample size using a simple random sample method. After the analysis of the questionnaires, the study showed that these two service farmers are lacking access to messages. The significant differences between farmers' perception of quality attributes within private and public services are; access to mobile-based extension services, utilization of mobile-based extension services, timeliness of mobile-based extension services as perceived by farmers, trust in mobile-based extension services, satisfaction of mobile-based extension services and sharing information of mobile-based extension services as perceived by farmers. Finally, the study reveals that it is very important to improve living stand for farmers with other actors that can support farmers using mobile-based extension services that can link farmers and other stakeholders in the agricultural value chain [12].

Today there is an introduction of digital farming initiatives where almost all of the agribusiness activities will be carried out using the web-based mobile system, The research is by one of the leading agencies on the business intelligent agile, automated and the cloud. The mission is to improve farmers' livelihood via technology by implementing smart villages, sustainable ecosystems, and digital transformation. The main objective is to improve crop production and efficiency [13].

The study aimed at assessing the farmer's willingness to adopt a new model technology Willingness-To-Accept (WTA) for their product. Nevertheless, this rapid development of technology mobile has revolutionized the market system face regarding agriculture. The study assessed the WTA model mobile app in the market to determine the product. The study uses an FGD method and interviews where 112 farmers are being interviewed using purposive sampling. The research uses Extended Technology Acceptance Model to assess the WTA. The study found that the current situation had a detrimental influence on farmers' WTA [14].

A study aimed at figuring out the impact of mobile devices especially mobile phones regarding the services provided by MTN Nigeria which is the message that concerns the agricultural specialist to graduate from universities in Nigeria during the 2018 period. The content of the messages was examined by the researcher who later compared and categorized them into four categories; evidentiary, local, descriptive and striking thereby encouraging the unemployed to make constructive decisions about their employment. Generally, the results of the research demonstrate that the messages sent to mobile phones are effective means in the attraction of qualified specialists to the work in the agriculture sector of the county. The research also reveals that the graduate of universities benefited from mobile phone services because now mobile phone is an effective means of not only communication but also forming certain tastes and values. Finally, the most important result of this research is the demonstration that due to the receiving agro-informational hints from unemployed graduates of universities, a large number of them found employment, at the same time, those who did not regard this information remained unemployed [15].

The study reveals that the role played by the market information system contributes to reducing the asymmetries of information and it has promoted competitiveness and improved efficiency in the market networking system. But also lack of necessary knowledge, skills, and experience in disseminating the information in the market and bargaining trader's capabilities over the agricultural chain is a problem among the farmers and stakeholders in Nigeria. The study finds that mobile devices can help and enhance farmers of Nigeria as a tool for agribusiness-related activities in the country, where the mobile phone can help farmers with their marketing strategy. The study proposed a system which implemented PHP language and MySQL and embedded JavaScript and phone gap/Cordova. The researcher uses XAMPP to manage the database of the proposed system. The system was successfully tested and validated using 50 respondents which at last returned a higher acceptance rate to stakeholders [16].

A literature review attempts to figure out the awareness regarding the use of a mobile phones concerning agribusiness in the Southwest part of Nigeria and the challenges. By the theory of information and communication technology for development, survey and FGD methods were employed. A questionnaire and FGD guide were used to collect data. Findings show that the radio is the most mobile feature used by the farmers with the rate of 75% and the most mobile service

and feature used by the farmers is voice call with the rate of 83.4%. This research shows that mobile phones have significantly increased the farmer's income and reduced transaction and transportation issues faced by the farmer living in the rural area of the country Nigeria. Finally, the research shows that mobile phone services can improve the living standard of farmers living in rural areas of the developing country [9].

The study [17] focuses on exploring the fact that deploying information through mobile phone gives a significant effect on agricultural information services (M-Agri services) that can revolutionize agriculture and improve smallholder farmers' livelihoods in Africa. Globally, the advent of this mobile Agric involves facilitating farmers' access to financial services. Numerous published literature sources [17], [3], [4] justify the potential advent of mobile agri services in Africa and none of them explore their sustainability. The study uses scoping review method and focus on published literature review. This study figures out the necessary changes, provision, and sustainability of these services in Africa. Findings reveal that while designing

the services of these mobile applications there are things needed to be considered and should not be neglected during the implementation process that can employ the practice, beliefs, literacy, skills culture, and demand [17].

## V. RESULTS AND FINDING

### A. Framework

The framework uses three-tier architecture to complete the overall design of a web-based mobile operating system. The first part of services refers to the web browser of the mobile terminal, whose main function is to provide users with user/commodity information and related services; the second service is mainly responsible for the corresponding business processes of e-commerce, including registration and login, online transaction and payment, information management of buyers and sellers, the last service part, the main function is to access and manage the database, including querying, reading, adding, deleting and modifying data tables.

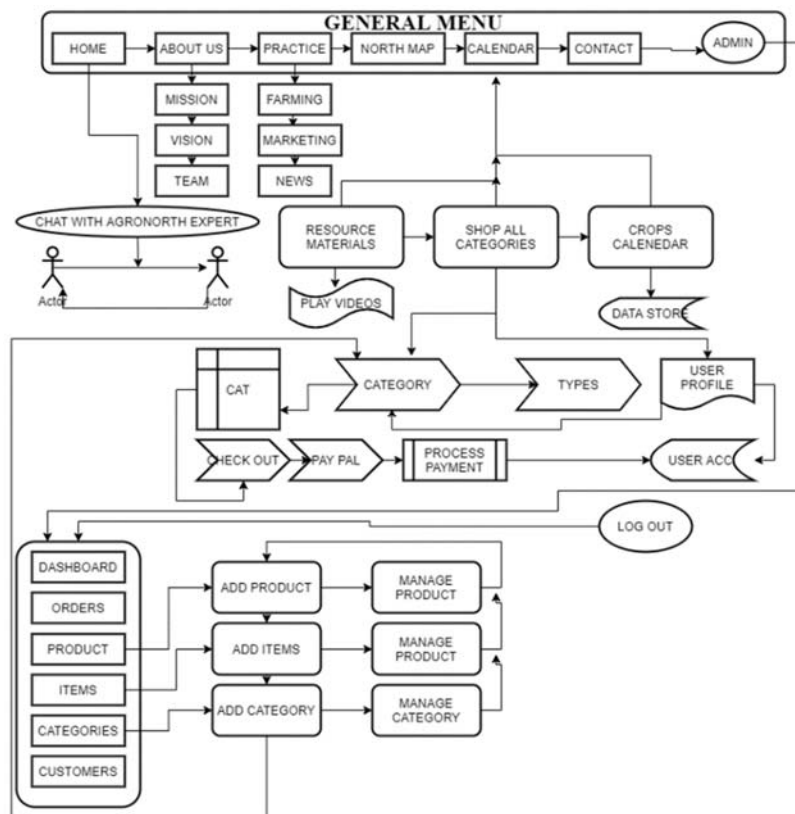


Fig. 1 Conceptual framework

### B. Use Case Diagram

Purpose: Provide top-level use cases for a web customer purchases, chatting, viewing resource materials and making practice online.

### C. Class Diagram

The class diagram of the proposed system which shows the

model of online shopping and other agribusiness-related activities from the classes, with their properties and attributes. This diagram explains how this model of the proposed system can operate and make the system standard.

### D. Sequence Diagram

Fig. 4 is the Sequence Diagram of AgriNorth proposed system. The diagram shows the interaction and details on how

system operations are carried out. Sequence Diagrams deal with time focusing on an interaction visually by using the vertical axis of the diagram to represent the time what messages are sent and when.

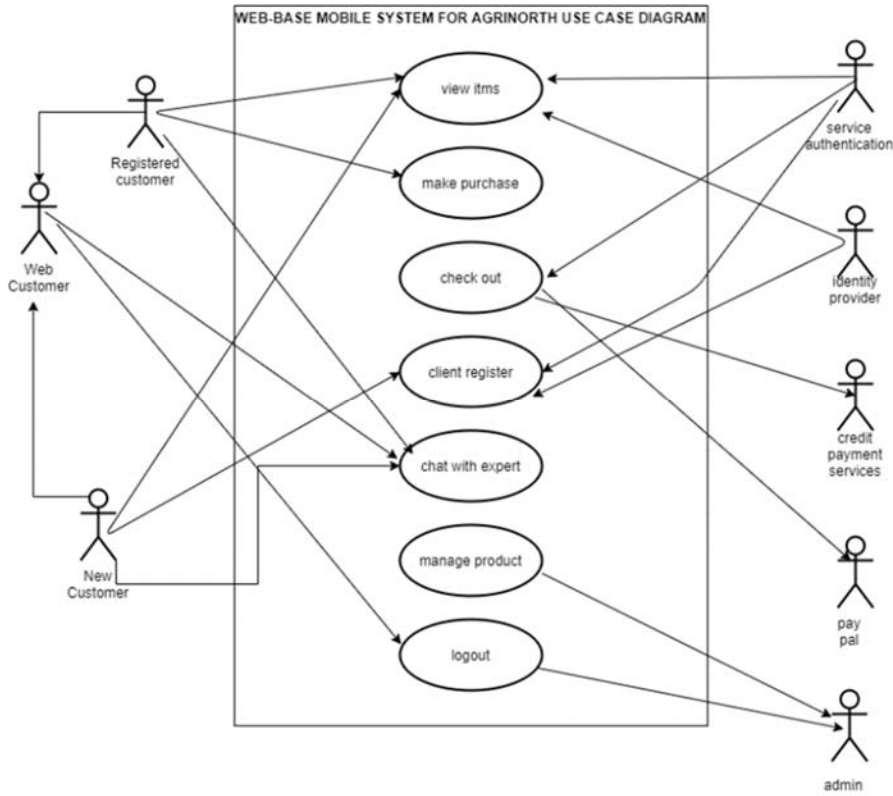


Fig. 2 Use case

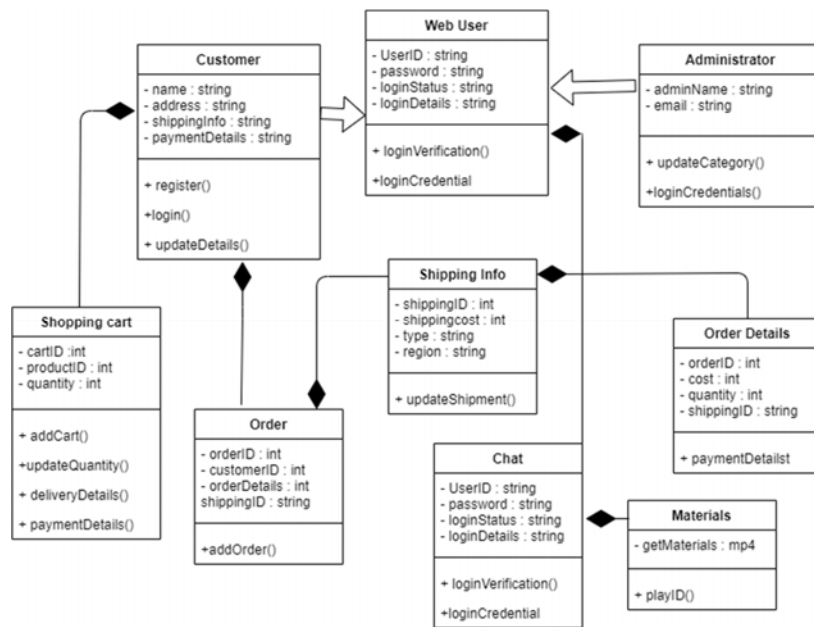


Fig. 3 Class diagram

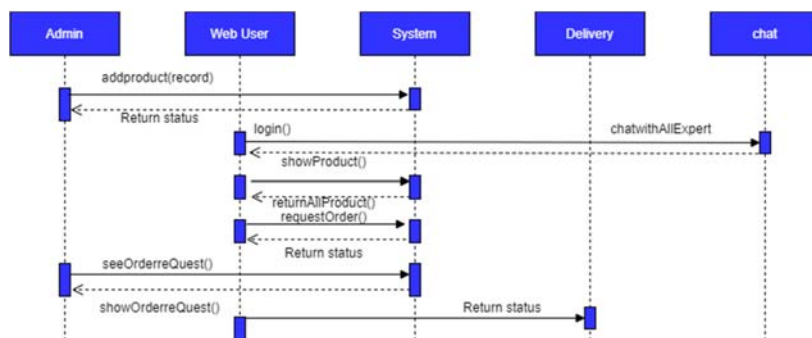


Fig. 4 Sequence diagram

E. Home Page of the Implemented System

TABLE I  
FREQUENCY AND PERCENTAGE OF DISTRIBUTION

Responses	Frequency	Percentage
Mobile Phone	230	230/304*100/1=75.7%
Mobile Radio	40	40/304*100/1=13.2%
Television	20	20/304*100/1=6.6%
Extension workers	14	14/304*100/1=4.6%
Total	304	100%

TABLE II  
HYPOTHESES TESTING

Responses	Fo	Fe	Fo-Fe	(fo-fe) <sup>2</sup>	(fo-fe) <sup>2</sup> /fe
Mobile Phone	230	101.3	128.7	16563.69	163.5
Mobile Radio	40	101.3	-61.3	3757.69	37.1
Television	20	101.3	-81.3	6609.69	65.2
Extension workers	14	101.3	-87.3	7621.29	75.2
Total	304				341

- H0. Farmers in Kebbi do not use an alternative medium to get agri-information.
- H1. Farmers in Kebbi use alternative mediums to get agri-information.

Therefore:  $X^2 = 341$ ;  $Df = k - 1 = 4 - 1 = 3$ .  $K = \text{categories/column}$ ;  $N = \text{Universe} = 304$ ;  $\text{Expected frequency} = (P) = 0.05$  under  $0.05 = 7.81$ ;  $\text{Table value} = 7.81$ . Since the calculated chi-square value is 341 and the table value is 7.81, the research hypothesis is accepted while the null is rejected.

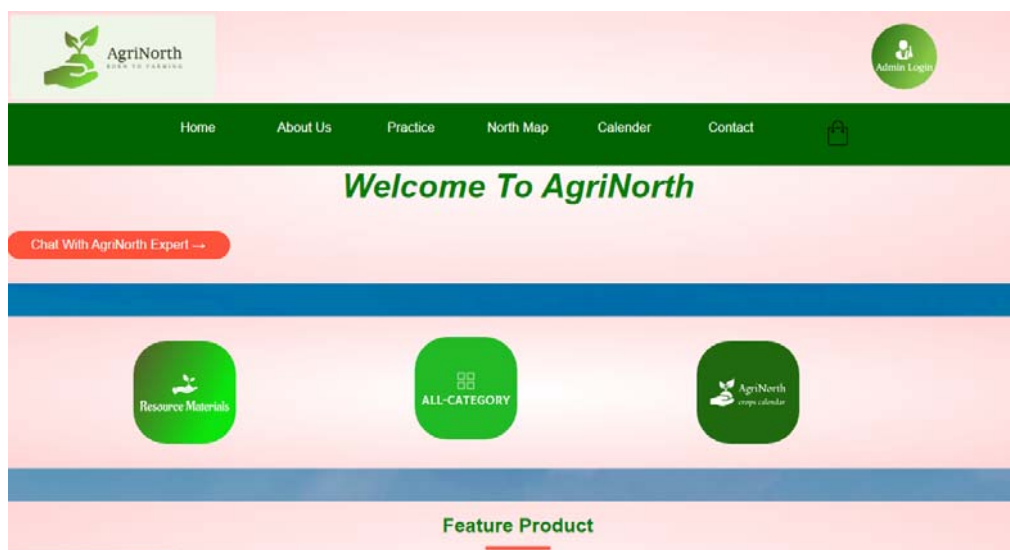


Fig. 5 Home page of the implemented system

VI. CONCLUSION

This research revealed the tremendous impact of web-based mobile systems on agricultural information among Kebbi farmers. It also revealed some problems with web-based mobile system usage among Kebbi farmers. The web-based mobile system enables farmers to communicate with team works from time to time through web-based mobile systems enhancing and collaboration with efficiency in the farming practices, because it gives room for sharing ideas between chief farmers and star farmers with the use of platform. From the research made, the

farmers agree that web-based mobile systems have a positive impact on their farming activities, methods, and systems. This is because web-based mobile systems enable farmers to communicate with other interested parties in the marketplace to acquire knowledge on how they can carry on their activities in such a way as to save cost and time. Web-based mobile systems help them to overcome this barrier. Most time web-based mobile systems hardly connect farmers when they want to verify certain facts about new information on farming practices. It is however not surprising to say that web-based mobile

systems have generally made a positive impact on the activities of farmers as their promised benefits far out weight the limitations. However, during the study it was observed that the use of web-based mobile system technology in the agricultural area needs to be considered. The following list was observed during the period of the study:

- It was observed that farmers living in developed countries are lacking many necessary skills and many facilities that can uplift their produce and increase their income.
- Lack of new knowledge impacts the use of new agriculture technology. The education facilities in the rural areas are very limited and cannot be accessed by all.
- Cost of technology i.e., using the web-based mobile system is very high and unaffordable for the common farmer.

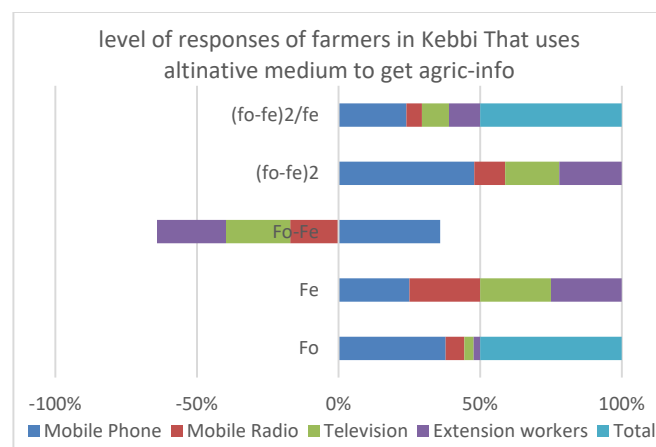


Fig. 6 Frequency distribution on the bar chart

### APPENDIX

#### SECTION A:

##### PERSONAL DATA

- Sex: Male  Female
- Age: 21-30  31-40  41-50  51 & above
- Marital Status: Single  Married  Divorced  Widowed
- Educational Attainment: Primary  Secondary  Tertiary  Islamic
- Occupation aside farming: Teacher  Carpenter  Trader  Others
- Religion: Muslim  Christian  Pagans

#### SECTION B

- Are web-based mobile system beneficial to farmers? Yes  No  No Idea
- Benefits of web-based mobile system to farmers?
  - To ascertain availability of farms implement.....
  - To confirm prices of product.....
  - To establish contact with markets.....
  - To verify market days.....
  - To determine the kind of production needed in market.....
- Do you encounter problem using web-based mobile system Yes  No  No idea
- The level of problem farmer's encounter in web-based mobile system usage?
  - Network congest.....
  - Lack familiarity with the plat form.....
  - Lack of knowledge.....
  - Poor network services.....
  - High product charges.....
- How often the farmers use web-based mobile system to get agric information in your community? Daily  weekly  quartile  Monthly  Yearly

Fig. 7 Questionnaire First Page

6. The level of new farm skills farmers would learnt from the use of web-based mobile system?

- How to improve farming method.....
- Improve crop species.....
- Knowledge of Agric supplements.....
- Storage method and facilities.....
- Commercial farming.....

7. What kind of information do farmers get from their star farmers or chief farmer of their various villages?

- How and when to reach the agric extension workers
- Market days
- Increase in price and how to get loan
- How to get good seeds and suitable type of fertilizer

8. Do you have a web-based mobile system for Local Agric Shopping in Kebbi?

- Yes  No  No idea

9. Do you like to have a new plat form where you can get authentic agric information?

- Yes  No  No idea

10. Do you like to have a plat form where you can shop agribusiness for kebbi farmers?

- Yes  No  No idea

11. Which alternative way you use in getting agric information?

- Mobile Phone
- Mobile Radio
- Television
- Extension Workers

Fig. 8 Questionnaire Second Page

### REFERENCES

- [1] Nigeria National Bureau of Statistics. (2017). Annual Abstract of Statistics 2016. Nigeria National Bureau of Statistics, 1(July). <http://www.nigerianstat.gov.ng/pdfuploads/ANNUALABSTRACT STATISTICS VOLUME-1.pdf>
- [2] Asked, F., On, Q., Nigerian, T. H. E., & Standards, L. (2020). *Nlss 2018/19 1. October 2019*, 1–7.
- [3] Workshop, A. (2020). *Current State of Nigeria Agriculture and Agribusiness Sector. September.*
- [4] Mansingh, P., & Abdese, F. (2016). Impact of Mobile Phone Technology on Agriculture and rural development: an analysis. *International Journal of Current Research*, 8(05), 31311–31317. <http://www.journalcra.com/sites/default/files/14790.pdf>
- [5] Kimura, M. (2020). *Introduction to Population Genetics. August*, 85–101. [https://doi.org/10.1007/978-981-15-6165-8\\_6](https://doi.org/10.1007/978-981-15-6165-8_6)
- [6] Tinuke, B. B., & Joseph, A. A. (2018). The Impact of Anchor Borrower Programme on Poverty Alleviation in Argungu Local Government Area of Kebbi State. *Journal of Public Administration and Governance*, 8(4), 239. <https://doi.org/10.5296/jpag.v8i4.14049>
- [7] Etikan, I. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1. <https://doi.org/10.11648/j.ajtas.20160501.11>
- [8] Singhal, R., & Rana, R. (2015). Chi-square test and its application in hypothesis testing. *Journal of the Practice of Cardiovascular Sciences*, 1(1), 69. <https://doi.org/10.4103/2395-5414.157577>
- [9] Singhal, R., & Rana, R. (2015). Chi-square test and its application in hypothesis testing. *Journal of the Practice of Cardiovascular Sciences*, 1(1), 69. <https://doi.org/10.4103/2395-5414.157577>
- [10] Anjum, R. (2015). Design of mobile phone services to support farmers in developing countries. *Master Thesis, December*, 2–72.
- [11] Chhachhar, A. R., Chen, C., & Jin, J. (2016). Mobile phone impact on agriculture and price information among farmers. *Indian Journal of Science and Technology*, 9(39). <https://doi.org/10.17485/ijst/2016/v9i39/98432>
- [12] Kassem, H. S., Shabana, R. M., Ghoneim, Y. A., & Alotaibi, B. M. (2020). Farmers' perception of the quality of mobile-based extension services in Egypt: A comparison between public and private provision. *Information Development*, 36(2), 161–180. <https://doi.org/10.1177/0266666919832649>
- [13] Introduction, A. (2018). *Digital Farming Initiatives.*
- [14] Diaz, A. C., Sasaki, N., Tsusaka, T. W., & Szabo, S. (2021). Factors affecting farmers' willingness to adopt a mobile app in the marketing of bamboo products. *Resources, Conservation & Recycling Advances*, 11,

200056. <https://doi.org/10.1016/j.rcradv.2021.200056>.
- [15] Gever, V. C. (2019). Effect of Mobile phone communication messages on participation in agriculture among university unemployed graduates. *Skhid*, 0(2(160)), 52–59. [https://doi.org/10.21847/1728-9343.2019.2\(160\).165721](https://doi.org/10.21847/1728-9343.2019.2(160).165721)
- [16] Abayomi-Alli, A., Misra, S., Dada, M., Alonge, C. Y., Agbaegbu, J. B., Arogundade, O. 'Tale, & Ahuja, R. (2021). *A Mobile-Based Market Information System* (Issue July). Springer International Publishing. [https://doi.org/10.1007/978-3-030-76736-5\\_4](https://doi.org/10.1007/978-3-030-76736-5_4)
- [17] Emeana, E. M., Trenchard, L., & Dehnen-Schmutz, K. (2020). The revolution of mobile phone-enabled services for agricultural development (m-Agri services) in Africa: The challenges for sustainability. *Sustainability (Switzerland)*, 12(2). <https://doi.org/10.3390/su12020485>