Smart Agricultural Technology 8 (2024) 100501

Contents lists available at ScienceDirect

Smart Agricultural Technology

journal homepage: www.journals.elsevier.com/smart-agricultural-technology

Farmers' perceived rating and usability attributes of agricultural mobile phone apps

Gbolagade Benjamin Adesiji [a], Joy Yetunde Adelowo [a], Sola Emmanuel Komolafe [a,*], Temidire Tioluwani Adesiji [b]

[a] Department of Agricultural Extension and Rural Development, University of Ilorin, Ilorin, Nigeria
[b] Department of Computer Engineering, University of Ilorin, Ilorin, Nigeria

ARTICLE INFO

Keywords:
Agricultural mobile phone applications
Usability
Benefits
Constraints

ABSTRACT

Cassava crop is in the forefront among the arable crops mostly cultivated in Nigeria. It is a crop that International Institute of Tropical Agriculture (IITA) have invested more efforts to develop mobile digital solutions for farmers to address some of the agronomic issues threatening its productivity. The ultimate aim of the digital solution is to bring innovations closer to farmers as well as to bring about the transformation needed to achieve food security in Africa. However, farmers' (users) quality rating and usability of agricultural mobile apps remains uncertain thereby, creating knowledge gap. Feedbacks of users are critical to inform developers of the apps about necessary modifications. This study therefore examined the usability attributes of Agricultural Mobile Phone Applications (AMPAs) among cassava farmers in South-west Nigeria using users-centered approach. Because of the selected crop, apps evaluated in this study were Akilimo App, Airtel 4-21 call App and IITA herbicide calculator App. Akilimo App is an advisory tool that provides site-specific recommendations to cassava farmers in order to increase their cassava-based cropping systems; Airtel 4-2-1 call App provides a voice-based tutorial on cassava production, weather, education, rice amongst others by simply dialing 4-2-1 on any mobile phone with an Airtel sim card; while IITA herbicide is a mobile application developed to prevent herbicide abuse, such as over-dosing and/or under-dosing. Four hundred and ten (410) cassava farmers were recruited as respondents for the study. Data were analyzed using both descriptive and inferential statistics, including frequency counts, percentages, means and standard deviation. As the major contribution, it was shown for the first time, how users (farmers) rated the three Apps in terms of engagement, functionality, aesthetics, information quality, and subjective quality while usability of the Apps were rated for efficiency, effectiveness, satisfaction, learnability, memorability, cognitive load, accuracy and error. Similarly, pattern of usage, benefits of usage and constraints to usage of the Apps were further investigated.

Introduction

Background to the study

In many developing countries like Nigeria, agricultural sector is essential to economic growth and one of the best strategies to reduce hunger and poverty [1]. In Nigeria, agriculture is responsible for about 35 % of the GDP, 37 % of merchandise exports, 75 % of rural household income, and 70 % of employment [2]. Given its enormous contribution to the livelihoods of African farmers and its potential to transform African economies, cassava is one of the six commodities designated by the African Heads of State as strategic crops for the continent [3]. According to Parmar et al. [4] more than 800 million people in Africa consume cassava as their primary source of calories, making it the second most significant staple food in Africa after maize.

Mobile applications (mobile apps) are software programmes similar to those in desktop and laptop computers, designed to run on mobile devices like smartphones and tablets [5]. They perform essential and specific functions, ranging from productivity, entertainment and access to information. They are designed to be interactive and provide users with mobile contents such as text, audio, recordings, images, graphics and videos. A number of mobile phone apps have been developed to improve cassava production in Nigeria and Africa. Notable mobile phone apps used in agriculture are Agrikore, FarmCrowdy, Verdant,

* Corresponding author.
E-mail address: kemmas04@yahoo.com (S.E. Komolafe).

https://doi.org/10.1016/j.atech.2024.100501
Received 27 February 2024; Received in revised form 2 July 2024; Accepted 2 July 2024
Available online 5 July 2024
2772-3755/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

AgroData, Hello Tractor, and Probityfarms apps [6]. Of these apps, Akilimo App, Airtel 4-2-1 call App and IITA herbicide calculator App are commonly known among cassava farmers.

The International Institute of Tropical Agriculture (IITA) and several other organizations developed numerous digital solutions to address some of the agronomic issues threatening cassava productivity in Africa so as to bring about the transformation needed to achieve food security. The selected Apps in this study were Akilimo App, Airtel 4-2-1 call App and IITA herbicide calculator App. Akilimo app is an advisory tool that provides site-specific recommendations to cassava farmers in order to increase their cassava-based cropping systems [7]. Airtel 4-2-1 call App is a component of Akilimo that provides a voice-based tutorial on cassava production, weather, education, rice amongst others by simply dialing 4-2-1 on any mobile phone with an Airtel sim card. IITA herbicide is a mobile application developed to prevent herbicide abuse, such as over-dosing and/or under-dosing of herbicides. Furthermore, because agriculture is location-specific, it is imperative that farmers receive specialized guidance on best practices, appropriate usage of inputs, precise weather forecasts, and up-to-date market and price information, hence harnessing the evolution of internet use and related digital technology like smartphones and apps, farmers can get the information they need as well as overcome limitations faced by the traditional agricultural extension service delivery [8]. In addition, each user of agricultural applications has a unique knowledge and comprehension of the app, and how well the app is used can also be influenced by the user's environment, friends, and personal traits like age, gender, and educational background. The increasing penetration of mobile networks and internet have continued to evolve and the statistics according to Nigerian Communication Commission (NCC) revealed that Nigeria boasted of 199.6 million mobile connections as of March 2022, and the number of active internet subscribers increased to 152.15 million at the end of October 2022 from 139 million recorded in October 2021.

In South-west Nigeria, cassava farming plays a vital role in the agricultural sector, contributing significantly to the region's economy. With the increasing prevalence of mobile phone applications designed for agricultural purposes, there exists a gap in understanding the usage of these technologies among cassava farmers. Most of existing studies tend to investigate the general use of mobile phone features without taking into consideration the difference between using a mobile phone and using a mobile phone application like agricultural apps [9] while none has examined the usage of mobile phone apps among cassava farmers.

Therefore, the extent to which farmers utilize agricultural mobile phone applications among cassava farmers in the study is not well-documented, leading to a limited understanding of the applications. It is against this background that the study intends to provide answers to the following research questions:

i. How do cassava farmers rate agricultural mobile phone applications using the Mobile Application Rating Scale (MARS)?
ii. What are the usability attributes of AMPAs as perceived by cassava farmers?
iii. What are the benefits derived by cassava farmers from the use of agricultural mobile phone applications? and
iv. Are there constraints faced by cassava farmers on the use of agricultural mobile phone applications in the study area?

Literature review

The Mobile Apps Rating Scale (MARS) is a 96 multidimensional and interdisciplinary instrument widely used to assess quality of mobile apps [10] using mobile apps developers as raters. The instrument is relevant in agriculture and has been applied to examine the quality of agricultural related apps among mobile app developers [11,12]. The instrument usually consists of four basic dimensions namely: aesthetics, engagement, functionality and information quality [10]. The standard score for each question on the rating ranges from 1 to 5 using a Likert scale [12]. Functionality validates the goal of an app and its purpose and potential users will search for apps in app stores using essential functionality as a keyword, demonstrating how significant this criterion is for an app [13]. The app should also offer quick cure or suggestions for users facing problems with their plants.

Unlike previous studies assessing the quality of agricultural mobile apps through mobile app developers as raters [11,12], this study employed users (farmers) as raters (users-rating) and thus, included subjective quality as the fifth dimension because it centers upon the users' perspectives of mobile apps [14]. Therefore, this study was premised on user-centered design approach. In software engineering, user-centered design for usability is considered as one of the most important measures of quality attributes of software [15,16]. Peischl et al. [16] prohibit the development of software that do not meet user requirements and therefore proposed user-centered design for integrated usability evaluation in a very early stage of software design by using paper prototypes. Peischl et al. [16] further recommends that early feedback of potential users may considerably improve the quality of the obtained design and product. This justifies the conduct of this study as findings were used to proffer recommendations to improve agricultural apps.

The term usability refers to the whole relationship between the user and the app product [17]. It directly affects how users feel about an app and may help them become long-term users. Even if people run into issues, a solution should be simple to discover. The usability attribute analyzes how simple a system interface is to be used [18]. Usability testing is critical in determining if an app is of sufficient quality to attract the attention of its desired user groups [19]. Because users were employed as raters in this study, efficiency, effectiveness, satisfaction, learnability, cognitive load, error occurrence and memorability attributes of the selected apps to determine usability were considered. Efficiency of an app refers to the quickness of the app to proffer solutions and or recommendations for users (farmers) facing problems with their cassava production. Asthetic features such as colour, font size, expressivity, and visual complexity have an impact on the attractiveness of mobile apps among users for learning and willingness to use [20]. Similarly, Lee et al. [21] established that visual aesthetics on mobile apps play an essential role in fostering interest, positive emotions, engagement, and enthusiasm across different domains.

Studies related to the use of agricultural mobile apps across the globe have highlighted the level of usage, attributes that influence the usage and constraints to use of agricultural mobile phone apps. The assessment of the use of agricultural mobile applications among smallholder farmers in Myanmar by Thar et al. [22] found that majority of the farmers agreed that agricultural mobile phone apps are useful to promote farm production however, inadequate knowledge and inadequate access to smart phones were the main constraints to usability of agricultural phone apps while younger farmers with higher level of education significantly supported usability agricultural phone Apps. Gururaja and Darukaswamy [23] asserted that Interactive Voice Response system empowered farmers in the remote areas to control devices (Irrigation motor). A study by Abdullahi et al. [24] found that poor network, high cost of airtime, cost of phones, complexity in operating phones and poor power supply were the main constraints facing farmers in the Northern part of Nigeria in using Farmer HelpLine app, mFishery app, Rural eMarket app, E-Wallet app, farmerConnect app, Agribiz app, m4agriNEI app and AgroSIM app in accessing farm related information. Another study conducted by Adekola et al. [9] among rice farmers in Nigeria showed that farmers mainly used mobile phone apps and have helped farmers to improve agricultural production, access extension services, determine profit and loss on investments, solve other agricultural problem and increase income. In Kenya, the use Double Hurdle approach by Mutuma et al. [25] revealed that farmers' decision to using mobile apps to access agricultural information is mainly influenced by ease of use of the applications, cost of the applications, and educational

status of the farmers. Okoroji et al. [26] concluded in a study in Nigeria that mobile phone apps attributes such as perceived usefulness supported usage while perceived risk and cost negatively affected usage. A study by Mdoda et al. [27] on the use of Mobile Phone App among farmers in South Africa, found that smallholder farmers' use of mobile apps has benefitted them to increase yield, access farm inputs, and agrarian information while challenges to use the apps were high cost of smart phone, poor network coverage, and mobile phone operating problem. Study in India revealed that the use of mobile phone apps helped farmers to effectively access farming news, and crop cultivation tips [28].

Methodology

Study area

This study was carried out in South western part of Nigeria. Southwest Nigeria comprises of six states namely Oyo, Ogun, Osun, Ekiti, Ondo and Lagos states. The six states lie between longitude 2°31[1] and 6°00[1] East and latitude 6°21[1] and 8°37[1] North with a total land area of 77,818 km2. The coordinates Latitude and Longitude in the three selected states for this study are as follows Oyo (8° 00′ 00′' N: 4° 00′ 00′'E), Ogun (7° 00′ 00′' N: 3° 35′ 00′'E), and Ekiti (7°40′ 00′' N:5° 15′00''E). The climate of Southwest Nigeria is tropical in nature, highly favourable for the agrarian activities of its teeming population and characterized by wet and dry seasons. The mean temperature ranges between 21 and 34 °C, while the annual rainfall ranges between 150 and 3000 mm. The wet season is associated with the southwestern monsoon wind from the Atlantic Ocean, while the dry season is associated with the northeastern trade wind from the Sahara Desert [29]. Oyo and Ogun states are known to have high producers of cassava farmers in South-west Nigeria. Also, Oyo and Ogun States were purposively selected for the study because some of cassava related digital tools (such as Akilimo, Airtel 4-2-1, Cassava Seed Tracker, Agric drive, IITA herbicide calculator, IITA NURU among others) have been launched and disseminated to some selected cassava farmers on the use of these apps by African Cassava Agronomy Initiative (ACAI) programme of IITA, Justice, Development and Peace Movement (a Non-Governmental Organisation) in Oyo State and Ogun State Agricultural Development Programme (OGADEP), and Akilimo Promoters. The economic activities in these states include; trading, handcraft, clothing, textile, pubic and civil service employment and agriculture. The predominant crops produced are cassava, maize, oil palm, vegetables, mango, cashew, cocoa, cocoyam tomatoes, pepper, kolanut among others.

Research design

The study applied user-centered and descriptive survey research designs. The choice of descriptive design was because this study intended to investigate rating and usability of agricultural mobile apps as perceived by users through survey using semi-structured interview schedule; while the data was presented in a descriptive form.

Population, sampling procedure and sample size

The population of the study comprised all the cassava farmers trained on agricultural mobile phone app in the selected South-West States in Nigeria. A three-stage sampling procedure was employed to select respondents for the study. The first stage involved the purposive selection of two states in South-West, Nigeria. Oyo and Ogun States because Akilimo, Airtel 4-2-1, and IITA herbicide calculator have been launched and disseminated to some selected cassava farmers on the use of these apps by African Cassava Agronomy Initiative (ACAI) programme of IITA, Justice, Development and Peace Movement (a Non-Governmental Organization) in Oyo State and Ogun State Agricultural Development Programme, among other promoters of agricultural apps. In addition to the aforementioned, cassava cultivation is one of the major crops grown in these areas. The second stage involved the purposive selection of two and three Local Government Areas (LGAs) in Ogun and Oyo State respectively. The third stage involved the proportionate random selection of 20 % in each LGA of 2050 trained farmers, resulting in a sample size of 410 respondents. Summary of the sampling stages are presented in Table 1.

Data collection and ethical approval

The primary data was collected using structured questionnaire. The instrument was subjected to content validity as it was assessed and modified by experts in the Department of Agricultural Extension and Rural Development, University of Ilorin, Nigeria. The comments and suggestions made by experts were used to restructure the instrument before being used for data collection. Also, Test-retest method was employed on 30 cassava farmers who were not included in the population of the study to conduct reliability of the instrument. Reliability was ascertained after obtaining Cronbach alpha reliability co-efficient (α) of 0.89.

Ethical approval to conduct the study was obtained from University of Ilorin Review Committee, University of Ilorin Nigeria with approval number UERC/ASN/2022/2313. Additionally, each participant gave verbal consent to participate before being given the research instrument to fill. The majority of participants completed the questionnaire in 2–5 min. Data was collected during the period of January 2023 to March 2023.

Measurement of variables

Agricultural Mobile Apps Rating Scale (MARS): The rating scale in this study assessed app quality on five dimensions. The rating scales were measured using the app quality standards clustered around the domains. Twenty (20) items were logically grouped according to objective dimensions of engagement (five items), functionality (three items), aesthetics (three items), information quality (six items). The instrument also included three items that were deemed more subjective as they include questions such as the following: "Would you recommend this app to other farmers who might benefit from it?" "Would you pay for this app?" and "What is your overall 5-star rating of the app?" Each question was scored in a range of 1 to 5 using a 5-points rating scale from "1 Poor", "fair", "Average" "Good" and "5 Excellent". The average score of total numerals assigned to scales (3.0) was used as benchmark for high rating value where dimension and domain with 3.0 and above were considered high rating while mean value less than 3.0 were considered as low rating.

***Usability attributes of Agricultural Mobile Apps*:** The usability scale in this study assessed app on five attributes. Fourty-four (44) items were logically grouped according to objective attributes of efficiency (8 items), effectiveness (5 items), satisfaction (6 items), leanable (5 items), cognitive load (5 items), accuracy and error (10 items), and memorability (5 items). These items were placed on 5-point Likert type scale.

Table 1
Summary of Sampling Procedure and Sample Size.

Stage 1	Stage 2	Stage 3	
Purposive selection of two States	Purposive selection of LGAs	Proportionate random selection of cassava farmers	20 % of trained cassava farmers
Oyo State	Afijo	330	66
	Akinyele	425	85
	Iseyin	505	101
Ogun State	Ijebu ode	375	75
	Odeda	415	83
Total		2050	**410 Cassava farmers**

The scales are strongly agree, agree, undecided, disagree and strongly disagree while scores of 5, 4, 3, 2 and 1 were assigned respectively for positively worded statement but reverse was the case for negatively worded statements. Additionally, the pattern of usage of the apps was measured on 3-point Likert type scale. The scales were always, occasionally, rarely while scores of 3, 2, and 1 were assigned respectively.

***Benefits of using of Agricultural Mobile Apps*:** Attributes of agricultural mobile apps innovation were expected to offer some benefits to users. Benefits in this study were perceived the relative advantages of how much better the agricultural mobile apps was than the traditional methods of accessing agricultural information that preceded it [30]. The respondents were provided with the list of 15 statements relating to benefits on how it has improved effectiveness, efficiency and accuracy of performing agronomic practices, access to farm advisory services and cost of operations in cassava production. Benefit statements were measured on a 5-point Likert type scale. The scales were great benefits, high benefits, moderate benefits, little benefits, and no benefits while scores of 5,4,3,2 and 1 were assigned respectively. Mean score and standard deviation of each benefit were generated and used to rank the benefits from 1st to 15th position, where 1st position indicates the topmost area of benefit while 15th position represents the least area of benefit.

***Constraints severity to use of Agricultural Mobile Apps*:** this study adopted the method of constraint severity [31] to assess experience based rating on the degree of seriousness of limiting factors that hinders the effective use of agricultural mobile apps among cassava farmers. A list of 14 constraints were presented to respondents to indicate the level severity of each constraint on a 4-points rating scale of very severe, severe, not severe and not a constraint which were scored 4, 3, 2 and 1 respectively. Mean and standard deviation of each constraint were generated and used to rank the constraints from 1st to 14th position, where 1st position indicates the topmost severe constraint and 14th position represents the least severe constraint.

Data analysis

Data were analyzed using descriptive statistics including frequency, percentages, mean and standard deviation with the aid of Statistical Package for Social Sciences (SPSS) version 23.

Results discussion

Cassava farmer's rating scale on agricultural mobile phone apps

The MARS framework provides a structured and comprehensive approach to evaluate mobile apps across multiple dimensions. The framework was used to assess the quality of selected agricultural mobile phone apps for cassava farmers, allowing for a systematic evaluation of the app's engagement, functionality, aesthetics, information and subjective quality.

According to Table 2, findings from the study on engagement of the agricultural mobile apps revealed that Akilimo ($\bar{x} = 3.23$) and Airtel 4-2-1 ($\bar{x} = 3.86$) were rated high while herbicide calculator ($\bar{x} = 1.39$) was rated low. This implies that some of the engagement subdomains of herbicide calculator were not applicable to farmers when compared with Akilimo and airtel 4-2-1 which were considered engaging and fit for purpose because they were able to improve their knowledge about cassava farming and were able to press the right keys on their devices with no stress. This is in line with the findings of Gururaja and Darukaswamy [23] who asserted that Interactive Voice Response (IVR), is an automated telephone system that combines pre-recorded messages with a dual-tone multi-frequency (DTMF) interface that engage callers such as farmers, allowing them to access information such as agricultural advice messages using the keys on a device through menu selection without seeing an expert physically. Apps functionality validates its aim and purpose. Essential functionality is a keyword that people (farmers) use while searching for apps in app stores, indicating how important functionality is for an app [12].

Furthermore, the functionality sub domains on Table 2 revealed that herbicide calculator was rated high ($\bar{x} = 3.55$) while Akilimo was rated low ($\bar{x} = 2.83$) on functionality rating due to some technicality errors. This implies that farmers can make immediate judgment on any app they install based on the immediate user experiences and functionality. Most farmers will immediately uninstall the app if the user experience and

Table 2
Summary of users' responses on mobile app rating scale in items, subdomains mean, and standard deviation.

Mobile App Rating Scale and subdomains	Herbicide calculator		Akilimo		Airtel 4-2-1	
	Metric mean (sd)	Average mean	Metric mean (sd)	Average mean	Metric mean (sd)	Average mean
Engagement						
Entertainment	1.39 (0.34)	**1.91**	3.11 (0.33)	**3.23**	4.01 (0.33)	**3.86**
Interest	1.13 (0.81)		3.31 (0.41)		4.06 (0.45)	
Customization	1.01 (0.84)		2.76 (0.44)		2.96 (0.62)	
Interactivity	2.02 (0.15)		2.76 (0.82)		3.80 (0.45)	
Target group	4.02 (0.34)		4.23 (0.25)		4.45 (0.21)	
Functionality						
Performance	3.00 (0.50)	**3.55**	2.16 (0.66)	**2.83**	4.43 (0.56)	**4.27**
Ease of use	3.42 (0.67)		3.01 (0.81)		4.10 (0.45)	
Navigation	4.22 (0.59)		3.31 (0.59)		–	
Aesthetics					–	
Layout	4.01 (0.98)	**2.92**	4.03 (0.76)	**3.89**	–	**–**
Graphics	2.55 (0.76)		3.02 (0.51)		–	
Visual appeal	2.21 (0.38)		4.61 (0.75)		–	
Information quality					–	
Accuracy of app description	4.56 (0.93)	**4.38**	3.39 (0.68)	**3.95**	4.17 (0.55)	**4.34**
Goals	4.51 (0.34)		3.79 (0.56)		4.62 (0.71)	
Quantity of information	4.12 (0.45)		3.98 (0.87)		4.45 (0.34)	
Quality of information	4.58 (0.72)		4.32 (0.45)		4.63 (0.91)	
Credibility	4.70 (0.44)		4.75 (0.61)		4.14 (0.88)	
Evidence base	3.81 (0.56)		3.45 (0.86)		4.00 (0.72)	
Subjective quality						
App recommendation	4.23 (0.25)	**3.76**	3.02 (0.51)	**2.41**	4.12 (0.83)	**4.32**
Will you pay for the app	2.50 (0.86)		1.99 (0.78)		4.23 (0.55)	
5-star rating	4.56 (0.93)		2.22 (1.20)		4.62(0.71)	

Source: Field survey, 2023.
Note: Numbers in the parentheses are standard deviation; sd = Standard deviation.

functionality does not meet their expectations. Airtel 4-2-1 app ($\bar{x} = 4.27$) was rated high on functionality. This is due to the fact that it provides self-service to farmers, it is accessible anytime, anywhere, toll-free and is available nation-wide in the three major Nigerian languages. Existing evidence from both Kenya and India revealed that mobile phone based agricultural advice has been shown to spur behavioral change among farmers and to lead to increased yields [32]. Findings of this study show that the visual aesthetics of herbicides calculator app ($\bar{x} = 2.92$) was rated low. This may be due to the layout and graphics of the app. The aesthetics of Akilimo ($\bar{x} = 3.89$) was rated high because respondents preferred the layout and graphics in terms of app colour.

On information quality domain, the selected agricultural apps, herbicide calculator ($\bar{x} = 4.38$), Akilimo ($\bar{x} = 3.95$), airtel 4-2-1 service ($\bar{x} = 4.34$) were rated high by users. This inferred that the information on these apps meet the needs of the farmers by providing relevant information on agronomic practices, herbicides calculation and the information can help farmers make better decisions about when to plant, fertilize, and harvest their crops. Finding of this study is in line with a report by Dione et al. [33] who found that trained farmers who used agricultural mobile app (Interactive Voice Response app) acknowledged that the app has effectively helped in accessing quality information on biosecurity measures and were satisfied with the level of African swine fever control in Uganda. Regarding the apps' subjective quality, 4-2-1 call app (4.32) and herbicides calculator app (3.76) were rated high as 5 star apps that could be paid for and recommended to other users. However, mean rating for Akilimo (2.41) was low as 5 star app that could be paid for and recommended to other users.

Perceived usability attributes of respondents

Users' usability evaluation of software design by using paper prototypes helps researchers to proffer recommendations to developers while feedbacks of potential users may considerably improve the quality of the obtained design and product [16]. Findings presented in Table 3 show that, the cassava farmers' rating of efficiency attributes for airtel 4-2-1 was high ($\bar{x} = 3.91$). Users' responses indicating high efficiency of airtel 4-2-1 could be attributed to timely feedback of requests and ease of understanding of the feedback. Results further showed that efficiency attributes of herbicides calculator app was high ($\bar{x} = 3.83$), this indicates that users of the app achieved high rate of task success in a

Table 3
Distribution of respondents on usability attributes.

Usability Attributes	Herbicide calculator		Akilimo		Airtel 4-2-1	
	Metric mean(sd)	Average mean	Metric mean	Average mean	Metric mean	Average mean
Efficiency						
Site specific recommendation	–	**3.83**	–	**2.64**	3.93(1.25)	**3.91**
Land preparation method	–		2.77(0.33)		3.89(1.64)	
Planting densities	–		–		3.88(0.32)	
Planting and harvesting dates	–		–		3.86(1.42)	
Data entry time- Time to enter the data	–		2.56(0.83)		–	
Tasks time- time to accomplish given tasks	3.81(0.50)		2.78(0.93)		–	
Response time of having the response to the requested information	3.90(1.21)		2.66(1.41)		3.95(1.19)	
How many clicks (touch) to solve the task?	3.77(1.84)		2.45(0.71)		3.97(0.67)	
Effectiveness						
How many steps to finish a given task	3.87(0.95)	**3.90**	2.35(1.50)	**2.38**	3.88(0.42)	**3.77**
How many tasks have been solved in the predefined time	3.93(0.61)		2.13(1.23)		3.97(1.19)	
How many time taking on screen	–		2.66(0.46)		–	
Number of time to make Voice calls	–		–		3.81(1.22)	
How many errors have been Zero error	–		–		–	
Satisfaction	–		–		–	
User friendly	3.79(1.00)	**3.80**	3.44(1.37)	**3.42**	3.89(0.32)	**3.93**
Confidentiality	3.65(1.03)		3.22(0.61)		3.93(1.25)	
Ease to navigate	3.89(0.93)		3.51(0.45)		3.98(0.66)	
User interface	–		3.78(1.17)		3.87(1.02)	
Does the application help user to recover from error	–		3.10(0.22)		–	
Are you satisfied with the application	3.88(0.89)		3.49(0.31)		3.99(0.99)	
Learnable						
Is the application easy to learn?	3.91(0.66)	**3.75**	3.22(1.37)	**3.51**	3.88(0.38)	**3.89**
Is the language Simple to understand?	3.90(1.07)		3.56(0.53)		3.91(1.04)	
Does the app encourage local language?	–		–		3.90(1.38)	
It is interactive	–		–		3.94(0.91)	
The time taken the user to learn is long	3.45(0.66)		3.66(0.81)		3.85(0.33)	
Cognitive load						
Less mental work is required	3.90(1.01)	**3.88**	3.56(1.17)	**3.65**	3.89(0.78)	**3.91**
Less manual calculation is involved	3.97(1.38)		3.61(0.78)		3.96(0.08)	
Easy to comprehend	3.77(1.00)		3.87(0.91)		3.95(0.51)	
It saves time	3.89(1.05)		3.33(0.61)		3.92(0.38)	
Accuracy is ensured	3.91(0.91)		3.88(0.45)		3.81(1.10)	
Accuracy and Error						
It is error free	3.96(1.10)	**3.93**	3.22(0.67)	**2.90**	3.89(0.34)	**3.83**
Guides against human error	3.98(1.12)		3.18(1.31)		3.80(0.51)	
Less user error rate	3.91(1.04)		2.54(0.33)		3.95(0.42)	
Reliable result	3.89(0.89)		2.19(0.45)		3.87(0.43)	
Simplicity of result	3.98(0.60)		2.62(1.05)		3.77(1.12)	
East to install App	3.95(1.03)		3.33(0.87)		–	
Ease to input data	3.97(1.26)		3.20(0.42)		3.78(1.12)	
Ease to use output	3.90(1.19)		3.55(1.64)		3.80(0.71)	
Easy to update App	3.88(0.89)		2.71(1.38)		–	
Low technicality	3.87(0.91)		2.25(0.45)		3.75(1.04)	

Source: Field survey, 2023.
Note: Numbers in the parentheses are standard deviation; sd = Standard deviation.

manner of accuracy and speed, thereby maximizing efficiency and resources. The use of agricultural mobile apps has proven to improve efficiency in accessing timely agricultural information as well as performing of farm tasks [34]. Information supplied by users further indicated that Akilimo app had low usability ($\bar{x} = 2.64$) as the farmers could not complete some of the cassava tasks in the sub domain of efficiency. Thus, Akilimo app needs to be reviewed for better efficiency.

Regarding effectiveness of the apps, users indicated that herbicides calculator ($\bar{x} = 3.90$) and airtel 4-2-1 ($\bar{x} = 3.77$) were highly effective (mean ≥ 3.0) while Akilimo (2.38) had low effectiveness. Findings imply that herbicides calculator app provides accurate calculation of herbicides usable for weed control while airtel 4-2-1 app must have provided effective voice-based services that enables the users to achieve some task effectively.

Presentation of findings in Table 3 indicates that farmers derived high satisfaction (mean ≥ 3.0) from the utilization of airtel 4-2-1 app ($\bar{x} = 3.93$), herbicide calculator app ($\bar{x} = 3.80$) while Akilimo ($\bar{x} = 3.42$). This indicates that farmers were able to achieve the purpose of using the 3 apps. Learnability for the agricultural apps were rated high (mean ≥ 3.0) with airtel 4-2-1 app ($\bar{x} = 3.89$) indicated first position, herbicides calculator ($\bar{x} = 3.75$) was second position while Akilimo ($\bar{x} = 3.51$) was placed third. This shows that the apps are easy to learn in a short period of time regardless of the level of farmers' education. This attribute is expected to increase usability of airtel 4-2-1 app, herbicides calculator and Akilimo for cassava production. Cognitive workload revealed less mental work for airtel 4-2-1 app ($\bar{x} = 3.91$), easy to comprehend ($\bar{x} = 3.88$) and Akilimo app ($\bar{x} = 3.65$). From the findings accuracy was affirmed by farmers for herbicides calculator (3.93) and farmers in this study affirmed that repeated errors (Mean = 2.90) when using Akilimo apps and this may cause them stress and frustration.

On the scale of agricultural apps' accuracy and error, farmers agreed that airtel 4-2-1 call app guides against human error (($\bar{x} = 3.83$). This implies that the number of user errors and numbers of navigational errors can potentially have effects on farmers' performance, farmers' progress, and farmers' usage of mobile applications. A study carried out by Jake-Schoffman et al. [35] revealed that mobile application with 5 % improvement in usability attributes led to increase productivity of users by 35 %. Therefore, evaluating the usability of mobile applications is very important due to proliferation and usage of mobile devices among farmers. It is important to mention that variable with missing values implied no response from respondents because they were not applicable.

Table 4 described the patterns of app usage among cassava farmers. Findings showed that majority (65.0 %) of the respondents indicated they always utilized Airtel 4-2-1 app while more than half of the respondents (58.3 %) always utilized herbicides calculator app. The possible reasons for these are that the Airtel 4-2-1 app services do not require airtime or internet before farmers can access it, it is available in the three major Nigerian languages and it provides a voice-based tutorial on cassava farming and other crops. Furthermore, very few (14.4 %) of the farmers always utilized Akilimo app due to some technical errors such as inability to complete some tasks, and errors popping up while using the app.

Table 4
Distribution of the respondents by the pattern of usage.

Apps	Always Frequency (%)	Occasionally Frequency (%)	Rarely Frequency (%)
Herbicide calculator	87 (58.3)	45 (30.4)	16 (10.8)
Akilimo	56 (14.4)	71(18.3)	261 (67.3)
Airtel 4-2-1 (IVR) service	143 (65.0)	68 (25.0)	9 (4.09)

Source: Field survey, 2023.
Note: Numbers in the parentheses are percentage;% = percentage.

Benefits derived from using agricultural mobile phone apps

Table 5 revealed the most prominent benefits farmers derived from the use of agricultural mobile phone applications. Findings showed that herbicides calculator has helped to reduce wastage ($\bar{x} = 4.81$), and provides valuable guidance to farmers on cassava production ($\bar{x} = 4.80$). Other notable benefits were that farmers have access to agricultural information anytime ($\bar{x} = 4.62$) and it is a fast way of getting information ($\bar{x} = 4.52$). These findings agree with a report by Adekola et al. [9] who showed that the use of mobile phone apps has helped farmers to effectively access extension services, solve other agricultural problems and improve production output. Similarly Dhenuvakonda et al. [36] indicated that the use of mobile phone apps provides farmers an instant delivery of information in a more convenient way to individual owners, and is cheaper to deploy. Due to its interactive nature, user-friendliness, and acceptance among farmers, agricultural apps are reportedly the best way to engage and disseminate agricultural information to farmers [37].

Furthermore, it reduces noise in communication ($\bar{x} = 4.54$). These results corroborate the findings of Thimnu [38] who opined that farming apps eliminate the unnecessary information that usually accompanies other transmission channels. It also reduces transaction costs ($\bar{x} = 3.65$). This implies that most of the farmers view agricultural apps as beneficial in their farm operations and those mobile apps can enhance farmer's decision-making process in order to achieve more sustainable practices, and contribute to increasing cassava production.

Constraints encountered on use of agricultural mobile phone applications

Cassava farmers encountered several constraints on the use of agricultural mobile phone applications. In Table 6, the most noticeable constraints were data consumption ranked 1st, battery life of mobile phone and power management ranked 2nd, inadequate agricultural extension to train farmers on use of agricultural mobile phone apps ranked 3rd, and cassava farmers are unable to upload picture of diseased cassava plants ranked 4th. This may be due to the fact that agricultural mobile apps, especially those that utilize features like GPS or data-intensive processes, can consume significant battery power. If a farmer's mobile phone has a poor battery life or inefficient power management, it may limit their ability to use the app for extended periods without requiring frequent charging.

Table 5
Distribution of the respondents by the benefits derived from using agricultural mobile phone apps.

Benefits	Mean score	Rank
Herbicides calculator has help me to reduce wastage	**4.81**	1st
It provides voice-based tutorial to farmers on cassava production	**4.80**	2nd
It is easier to calculate herbicides	**4.69**	3rd
Access to agricultural information anytime	**4.62**	4th
It provides valuable guidance to farmers on cassava production	**4.60**	5th
It provides agronomic advice on cassava in respond to specific weather conditions	**4.54**	6th
It reduces noise in communications	**4.54**	6th
It is a fast way of getting information	**4.52**	8th
Airtel 4-2-1 service eliminate language barrier	**4.45**	9th
Agricultural apps enhance my effectiveness on farm operations	**4.30**	10th
It improves efficiency and accuracy	**3.87**	11th
I have more accurate and timely knowledge about cassava	**3.77**	12th
It reduces transaction costs	**3.65**	13th
It handy in the absence of expert	**3.58**	14th
Time savings. It has significant impact on the time required for daily, weekly and seasonal tasks	**3.20**	15th

Source: Field survey, 2023.

Table 6
Constraints Encountered on the use of Agricultural Mobile Phone App.

Constraints	Mean score	Rank
Akilimo app consumes excessive data	**2.45**	1st
Battery life and power management	**1.96**	2nd
Inadequate agric. extension to train farmers on use of agricultural mobile phone apps.	**1.89**	3rd
Unable to upload picture of cassava plants.	**1.62**	4th
Akilimo app does not provide recommendations	**1.39**	5th
Poor feedback on Akilimo	**1.36**	6th
Poor quality of internet connection.	**1.28**	7th
Lack of confidence about information privacy and security on agricultural mobile phone apps	**1.20**	8th
Language preference/ barriers	**1.06**	9th
Too many information to fill	**0.97**	10th
Complexity in operating the app	**0.90**	11th
Agricultural mobile phone apps are not users friendly.	**0.64**	12th
App voice command are not available in the three major Nigerian Languages.	**0.26**	13th
Voice command functionality are not integrated into the app to give access to all users	**0.23**	14th

Source: Field survey, 2023.

Conclusion and recommendations

The findings of the study provided an insight into the understanding of users (farmers) usability and quality rating of selected agricultural mobile apps (herbicides calculator, airtel 4-2-1 and Akilimo) in promoting cassava production in Nigeria. The study established that (farmers) users' rating were high for herbicide calculator, Akilimo and Airtel 4-21 apps for quality engagement, functionality, aesthetics information quality, and subjective quality. However, herbicide calculator had low engagement and aesthetics, Akilimo had low functionality and subjective quality while Airtel 4-2-1 had high rating for all domains. The usability of Airtel 4-2-1 (IVR) service was high, herbicide calculator was moderate while Akilimo was low. The highest benefits derived by farmers in using the apps were reduce wastage of herbicides, valuable guidance on cassava production and access to agricultural information anytime while the highest constraints facing the farmers in using the apps were Akilimo app that consumes excessive data, low battery life, and inadequate agricultural extension agents to train farmers on use of agricultural mobile phone apps.

- Ø To the developer of Akilimo that was rated with low functionality, low subjective quality, low usability and excessive consumption of data, it was recommended that offline functionality should be incorporated into Akilimo app. This allows farmers to access the app anywhere they go with offline capabilities ensuring that the farmers maximize the usability of the app. Additionally, Akilimo app's features for performance, navigation and ease of use for less educated farmers should be revisited for improvement. This improvement will enhance farmers' interest to pay for Akilimo app services and also to recommend to fellow farmers.
- Ø To the developer of herbicide calculator that was rated with low engagement and aesthetics, and moderate usability, features of the apps should be revisited to make it more entertaining, interactive, and visually appealing using attractive graphics and layouts. This is expected to increase pattern of usability of the app.
- Ø Regarding the inadequate agricultural extension to train farmers on use of agricultural mobile phone apps, it is recommended that government at all levels and other concerned private agencies should design relevant capacity building programs that will increase farmers' awareness and knowledge of agricultural mobile apps. Such programs should prioritize training sections for all cassava farmers who are non-users of Airtel 4-2-1 since their fellow farmers had ascertained the quality services the app provides. The findings from this study have called for future computer engineering studies to investigate causes of high consumption of data of agricultural mobile phone apps; and suggest probable solutions that will reduce the problem to developers.

CRediT authorship contribution statement

Gbolagade Benjamin Adesiji: Validation, Supervision, Methodology, Investigation, Conceptualization. **Joy Yetunde Adelowo:** Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Conceptualization. **Sola Emmanuel Komolafe:** Validation, Project administration, Investigation, Formal analysis, Data curation. **Temidire Tioluwani Adesiji:** Visualization, Software, Resources, Project administration, Data curation.

Declaration of competing interest

Authors of this manuscript declare no conflict of interest.

Data availability

Data will be made available on request.

References

[1] Gbughemobi, B., Nkamigbo, D.C., & Meludu, N.T. (2021). Analysis of accessibility and level of knowledge of farmers on the use of ICT among small holder rice farmers in Southeast, Nigeria. 8, 133–140.

[2] Ezeoha, A.E., & Igwe, A. (2019). The mobile phone revolution, the Internet and rural electricity : what are the implications for food security in Africa? 10.1177/0266666919884991.

[3] S. Feleke, V. Manyong, T. Abdoulaye, A.D. Alene, Assessing the impacts of cassava technology on poverty reduction in Africa, Stud. Agric. Econ. 118 (2) (2016) 101–111, https://doi.org/10.7896/j.1612.

[4] A. Parmar, B. Sturm, O. Hensel, Crops that feed the world: production and improvement of cassava for food, feed, and industrial uses, Food Secur. 9 (5) (2017) 907–927, https://doi.org/10.1007/s12571-017-0717-8.

[5] C. Costopoulou, M. Ntaliani, S. Karetsos, Studying Mobile Apps for Agriculture, IOSR Journal of Mobile Computing & Application 3 (6) (2016) 1–6, https://doi.org/10.9790/0050-03064449.

[6] S.O. Sennuga, T.O. Fadiji, Effectiveness of traditional extension models among rural dwellers in Sub-saharan African communities, Int. J. Adv. Comput. Res. 8 (04) (2020) 401–415, https://doi.org/10.21474/IJAR01/10791.

[7] Odularu, G., & Badiru, I., & Bello-Aliyu, F. (2023). Digital Disparities and COVID-19 Pandemic among Agrifood NMSMEs: A Zero-Sum Game ? A Publication of the NESG Non-Residential Fellowship Programme. https://nesgroup.org/download_resource_documents/DIGITAL%20DISPARITIES%20AND%20COVID-19%20PANDEMIC%20AMONG%20AGRIFOOD%20NMSMES%20A%20ZERO-SUM%20GAME_1692611676.pdf.

[8] K.A. Abdullahi, O.I. Oladele, O.J. Yusuf, Use of mobile phone applications by farmers in North West Nigeria, J. Agric. Ext. 23 (3) (2019) 182, https://doi.org/10.4314/jae.v23i3.16.

[9] O.A. Adekola, T.A. Akinyemi, K.G. Adeosun, S.E. Komolafe, Mobile phone applications (Apps) usage issues among rice (Oryza sativa) farmers in Obafemi Owode local government area, Ogun State, J. Home Econ. Res. 30 (2) (2023) 20–30.

[10] Y. Terhorst, P. Philippi, L.B. Sander, D. Schultchen, S. Paganini, M. Bardus, K. Santo, J. Knitza, G.C. Machado, S. Schoeppe, N. Bauereiß, A. Portenhauser, M. Domhardt, B. Walter, M. Krusche, H. Baumeister, E.-M. Messner, Validation of the mobile application rating scale (MARS), PLoS ONE 15 (11) (2020) e0241480, https://doi.org/10.1371/journal.pone.0241480.

[11] R. Sinclair, Sadia Nodi, Muhammad Ashad Kabir, Evaluating mobile applications for estimating soil properties: quality of current apps, limitations and future directions, Comput. Electron. Agric. 216 (2024) 108527, https://doi.org/10.1016/j.compag.2023.108527.

[12] A. Siddiqua, M.A. Kabir, T. Ferdous, I.B. Ali, L.A. Weston, Evaluating plant disease detection mobile applications: quality and limitations, Agronomy 12 (8) (2022) 1869, https://doi.org/10.3390/agronomy12081869.

[13] M. Nayebi, M. Marbouti, R. Quapp, F. Maurer, G. Ruhe, Crowd sourced exploration of mobile app features: a case study of the fort McMurray wildfire, in: Proceedings of the IEEE/ACM 39th International Conference on Software Engineering: Software Engineering in Society Track (ICSE-SEIS), Buenos Aires, Argentina, 20–28 May 2017, 2017, pp. 57–66.

[14] M.A. Kabir, S.S. Rahman, M.M. Islam, S. Ahmed, C. Laird, Mobile apps for foot measurement in pedorthic practice: scoping review, JMIR Mhealth Uhealth 9 (3) (2021) e24202, https://doi.org/10.2196/24202.

[15] Z. Hussain, W. Slany, A. Holzinger, Current state of agile user-centered design: a survey, in: USAB 2009 - Usability & HCI Learning from the Extreme, 5889, Springer, 2009, pp. 416–427. Lecture Notes in Computer Science.
[16] B. Peischl, M. Ferk, A. Holzinger, The fine art of user-centered software development, Softw. Qual. J. 23 (3) (2015) 509–536, https://doi.org/10.1007/s11219-014-9239-1.
[17] Q. Wei, Z. Chang, Q. Cheng, Usability study of the mobile library App: an example from Chongqing University, Libr. Hi Tech 33 (2015) 340–355.
[18] H.E. Payne, C. Lister, J.H. West, J.M. Bernhardt, Behavioral functionality of mobile apps in health interventions: a systematic review of the literature, JMIR MHealth UHealth 3 (2015) e3335.
[19] P. Weichbroth, Usability Testing of Mobile Applications: a methodological framework, Appl. Sci. 14 (5) (2024) 1792, https://doi.org/10.3390/app14051792.
[20] A. Ruf, C. Zahn, D. Agotai, G. Iten, K. Opwis, Aesthetic design of app interfaces and their impact on secondary students ' interest and learning, Comput. Educ. Open 3 (2022) 100075, https://doi.org/10.1016/j.caeo.2022.100075.
[21] Lee, C.S., Goh, D.H., & Goh, D.H. (2022). AIS Electronic Library (AISeL) Understanding the Visual Aesthetics of Mobile Apps in Everyday Life : the Influence Cute Aesthetics Understanding the Visual Aesthetics of Mobile Apps in Everyday Life : the Influence of Cute Aesthetics.
[22] S.P. Thar, T. Ramilan, R.J. Farquharson, A. Pang, D. Chen, An empirical analysis of the use of agricultural mobile applications among smallholder farmers in Myanmar, Electron. J. Inf. Syst. Dev. Countries 87 (2) (2020), https://doi.org/10.1002/isd2.12159.
[23] D.T.H.M. Gururaja, Interactive voice response system for agriculture, Int. J. Creative Res. Thoughts 11 (6) (2023) f463–f466. Available at, http://www.ijcrt.org/papers/IJCRT2306630.pdf.
[24] K.A. Abdullahi, O.I. Oladele, M. Akinyemi, Attitude, knowledge and constraints associated with the use of mobile phone applications by farmers in North West Nigeria, J. Agric. Food Res. 6 (2021) 100212, https://doi.org/10.1016/j.jafr.2021.100212.
[25] S.P. Mutuma, W.L. Ngare, E.K. Bett, C.N. Kamau, Extent of adoption of mobile phone applications by smallholder dairy farmers in Tharaka Nithi County, Kenya, Cogent. Food Agric. 9 (2) (2023), https://doi.org/10.1080/23311932.2023.2265225.
[26] V. Okoroji, N.J. Lees, X. Lucock, Factors affecting the adoption of mobile applications by farmers: an empirical investigation, Afr. J. Agric. Res. 17 (1) (2021) 19–29, https://doi.org/10.5897/AJAR2020.14909.
[27] L. Mdoda, M. Christian, I. Agbugba, Use of information systems (Mobile Phone App) for enhancing smallholder farmers' productivity in eastern cape province, South Africa: implications on food security, J. Knowl. Econ. (2023), https://doi.org/10.1007/s13132-023-01212-0.
[28] C.S. Kumar, Access and application of mobile agriculture apps among farmers in Tamilnadu, J. Crit. Rev. 8 (3) (2021) 271–280.
[29] T.O. Ojo, L.J.S. Baiyegunhi, Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria, Land Use Policy (2019) 103946, https://doi.org/10.1016/j.landusepol.2019.04.007.
[30] E.M. Rogers, Diffusion of Innovations, Free Press, New York, 2003.
[31] N.P. Jangwad, S.P. Salame, P.K. Wakale, T. Rathod, R.C. Khandvi, Constraints severity index of onion growers and their correlation with regards to cultivation, storage and market in Buldhana district of Vidarbha region, Agric. Update 12 (TECHSEAR-10) (2017) 2775–2779.
[32] R. Fabregas, M. Kremer, M. Lowes, R. On, G. Zane, L. Alexander, C. Corral, T. Harigaya, C. Misiati, C. Musungu, C. Myers, A. Nawar, C. Nekesa, W. Wanjala Oduor, V. Omenyo, V. Perez, M. Sheahan, SMS-extension and Farmer Behavior: Lessons from Six RCTs in East Africa. Working Paper. https://www.atai-research.org/wp-content/uploads/2020/05/textfarmers1.pdf.
[33] M. Dione, E. Kangethe, E.J. Poole, N. Ndiwa, E. Ouma, I. Dror, Digital extension interactive voice response (IVR) mLearning: lessons learnt from Uganda Pig Value Chain, Front. Vet. Sci. 8 (2021), https://doi.org/10.3389/fvets.2021.611263.
[34] B. Ahmad, A. Rouf, F. Khanom, Rozina Yeasmin Lucky, Mou Rani Sarker, Md Golam Rabbani, Md Naimur Rahman Ray, N Islam, Experience of farmers using mobile phone for farming information flow in Boro rice production: a case of Eastern Gangetic Plain, Soc. Sci. Humanit. Open. 9 (2024) 100811, https://doi.org/10.1016/j.ssaho.2024.100811.
[35] D.E. Jake-Schoffman, V.J. Silfee, M.E. Waring, E.D. Boudreaux, R.S. Sadasivam, S. P. Mullen, S.L. Pagoto, Methods for evaluating the content, usability and efficacy of commercial mobile health apps, JMIR Mhealth Uhealth 5 (12) (2017) e190, https://doi.org/10.2196/mhealth.8758.
[36] K. Dhenuvakonda, A. Sharma, K.P. Prasad, R. Sharma, Socioeconomic Profile of Fish Farmers of Telangana and Usage of Mobile Apps, Asian Journal of Agricultural Extension, Economics & Sociology (2019), https://doi.org/10.9734/ajaees/2019/v37i330268.
[37] N.K. Singh, N.H. Sunitha, G. Tripathi, D.R.K. Saikanth, A. Sharma, A.E. Jose, M.V. K.J. Mary, Impact of digital technologies in agricultural extension, Asian J. Agric. Ext. Econ. Sociol. 41 (9) (2023) 963–970, https://doi.org/10.9734/ajaees/2023/v41i92127.
[38] J. Thimnu, Africa's mobile agricultural revolution: farming apps in Sub-Saharan, Africa Juana Thimnu 7 (1) (2020) 1–11.