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AgFAB - A Farmer-centered Agricultural Bower

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Abstract

Digital Agriculture aims to raise agricultural productivity while empowering the farming stakeholders (especially the farmers) with the availability of ICT-based applications on smart devices. However, despite putting in much effort, smallholder farmers' willingness for adopting digital technologies is low in developing countries. In this study, following the principles of the human-design process, we investigated the smallholder farmers' core demands from mobile/computing application(s). Considering these core demands of the farming community, the developed prototypical interfaces were evaluated by farmers using the System Usability Scale (SUS) to check the acceptability of a proposed farmer-centered solution named AgFAB. The AgFAB prototypical interface design received an average SUS score of 72.37, which is an indication of an acceptable design. Moreover, the results of Paired T-test seem promising for the strong adoptability of AgFAB by farmers with reference to their aspect of usability in the agricultural context.

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1. Introduction

The conception of Digital Agriculture is based on the use of Information and Communication Technologies (ICT) to digitalize all possible agricultural activities related to the monitoring and management of crops, plants, trees, and livestock at small-/large-scale lands, farms, fields, orchards, and forests. In order to fulfill the feeding demands of the growing population, it is indispensable for farming stakeholders to adopt new approaches of the digital agriculture (either Precision Farming or Smart Farming). Agricultural digitalization not only makes farming practices more controlled, precise, and accurate but also increases production at reduced cost and low impact on environmental factors. The efficient handling of farm activities and optimized productivity are possible through the satisfaction of agriculture industry stakeholders (i.e., farmers, extension workers, researchers, food suppliers, etc.) with their usage of digital technologies [1] [2] [3] [4].

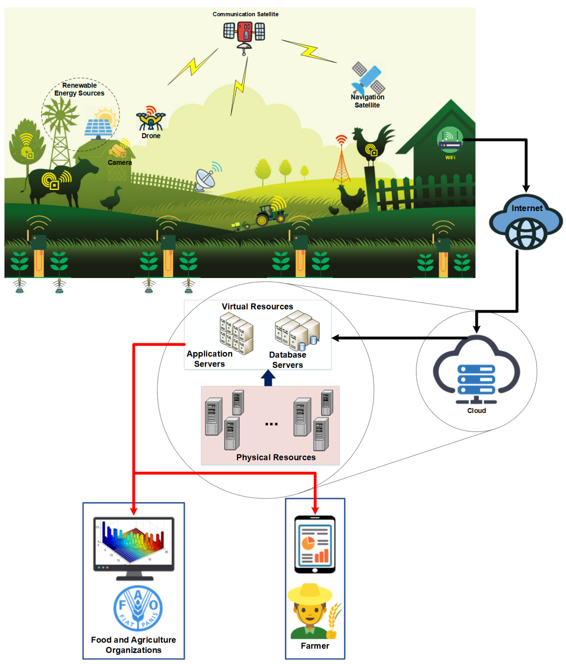

Figure 1. Digital Agriculture Ecosystem

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The satisfaction of the agricultural stakeholders (especially the farmers) is dependent on the availability and accessibility of in-time/on-time required information in a user-friendly form. Here, user-friendliness is very important because farmers (the main stakeholder of the agricultural system) are not well-educated and technology-aware (especially in developing countries). Therefore, highly technical digital agriculture is not possible without knowing the context of farming practices as well as designing of farmer-friendly interactive interfaces. At an abstract level, an ICT-based digital agriculture ecosystem that encompasses various agricultural operations is shown in Figure 1. From Figure 1, it becomes evident that the agriculture industry stakeholders are mainly interested in the availability of field-related information in some specific familiar format on (portable) computing devices. Therefore, it is very important to consider the designing and development of new dedicated software applications and devices while taking into account the ergonomics and usability of farmer interactive systems.

A number of digital farming software platforms (mobile+web) have been developed and provide invaluable assistance to farmers in developed countries for visualizing critical field data that is ultimately helpful in monitoring and measuring the impacts of their agronomic decisions. However, the usability of these applications is very low in developing countries. According to [5], two of the main reasons include the lack of user-friendly interfaces and the unavailability of standalone applications or dedicated devices that cover the core needs of a farmer.

The focus of this research work is three-fold, 1) investigation of farmers' core demands from mobile/computing application(s) in developing countries' scenarios 2) proposal of a dedicated farmer-centered solution, and 3) evaluation of farmers' acceptability to the proposed farmer-centered solution with reference to the aspect of usability. This study had been carried out at Burewala city of Vehari District in Punjab, Pakistan involving smallholder farmers of different age groups. In our investigations through formal and informal interviews and meetings with the farming community, we found that farmers are interested to have a dedicated device or mobile application with consolidated features covering the core requirements of their farming practices (i.e., current weather, [extreme] weather forecast, market prices for agricultural commodities including seed, fertilizer, pesticide, machinery, etc.).

Right now, the smallholder farming communities in this area are getting these types of relevant information using different social mobile applications and services (including Facebook groups, WhatsApp groups, SMS services, etc.). Considering the farmers' requirements, we designed and developed prototypical application interfaces (for our future product/application named AgFAB [Farmer-centered Agriculture Bower]). The results of System Usability Scale (SUS) show that farmers are inclined to adopt digital technology if their core requirements regarding routine farming practices are available in a consolidated form as smartphone application or dedicated device. Moreover, Paired T-Test results also advocates the farmers' acceptability for proposed AgFAB mobile application.

The rest of the paper is organized as follows: related work of the study is discussed in Section 2. The research question to evaluate the satisfaction score and adoptability of AgFAB is reported in Section 3. The results of the study have been discussed in Section 4. In Section 5, conclusion and future research work are reported.

2. Related Work

Concerning the development of agroecological systems, a number of computing devices and mobile/web applications have been developed to facilitate farmers. However, many of these devices/applications fall short of fulfilling the needs of the farmer. One of the obvious reasons for these failures was the absence or minimum involvement of farmers in the design process that is ultimately required to accomplish the *usability* perspective. Usability is the basic concept of Human-Computer Interaction (HCI) related to the development of easy-to-learn, easy-to-use, and less error-prone interactive systems while considering the involvement of users in User-Centered Design (UCD) process [6] [7].

HCI discipline emphasized the involvement of humans along with consideration of technology and environment in the design process. The UCD approach in HCI focuses on the user demographics, real-world environment, usability goals, tasks, and workflow in the design of (mobile/web) application interfaces. The usability goals include efficiency, effectiveness, safety, learnability, and user satisfaction. Therefore, concerning the UCD of agroecological systems, the continuous involvement of agricultural stakeholders through a feedback mechanism is a very important aspect. In general, concerning the ethnography of software developers, Woolgar [8] has pointed out that the UCD approach is essential to be considered for bridging the gap between system designers and end-users. Cooper in [9] explained that without the involvement of end-users in the design process, even talented software developers can not develop usable software.

Although, one of the underserved research domains of HCI is agriculture [10]; however, a few researchers have investigated the importance of the role of HCI in the development of digital agriculture systems. Parker

Figure 2. AgFAB Device Interfaces

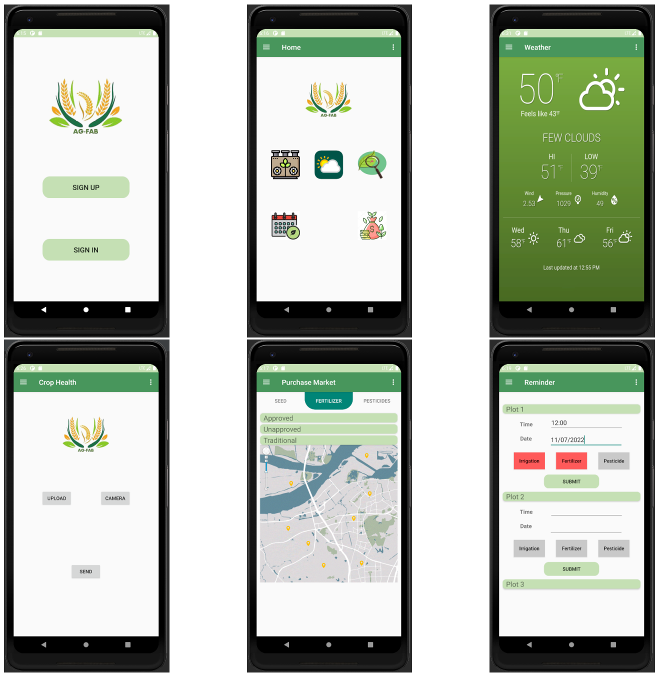


Figure 3. AgFAB Mobile App Interfaces

and Sinclair in [11] have reported that the adoption of a technology-centered approach is the main reason for the failure of the delivered device/tool/software that is not according to the needs of the farmers. Lindblom et al. [12] also put emphasis on the adoption of the UCD process for the development of digital agriculture applications. In [13] [14], authors have pointed out that the successful development of IoT-based digital agriculture systems is difficult without the involvement of farmers in the design process. Authors in [15] elaborated the significance of UCD in digital agriculture with the help of two case studies. Their investigations in terms of finding 1) the determinants of successful realization of digital agriculture system and 2) the extent of farmers' involvement advocate the collaborations of HCI researchers and agricultural scientists. Similar findings are also reported in [16], [17], [18] where authors have discovered that continuous user consultations are more effective in the development of digital agriculture systems.

In [19], authors found that presenting results in an unfamiliar and unacceptable format to the farmer is the result of the lack of UCD practices in the implementation of the agroecological monitoring system. Marques in his study [20] has also emphasized to consider the farmers' needs and expectations while considering their interaction with the technology (especially smartphone-based agriculture applications). Other than these investigations, considering the importance of UCD in digital agriculture, various smartphone, web, and desktop digital agricultural applications/systems have been developed. A few of these examples have been mentioned in Table 1. The proposed solutions (shown in Table 1) overlooked the scenarios and requirements of farmers in developing countries. That is the gap in knowledge this paper addresses using the HCI practices to improve the adoptability of agricultural technology in developing countries.

3. AgFAB, Farmer-Centered Agriculture Bower

In this study, we have investigated that although the digitalization of agriculture has been regarded as positive; however, despite putting much effort into the development of web/mobile-based agricultural applications, why the farmers' willingness to adopt such technologies is low in developing countries. In many developing countries, still farmers are reluctant to adopt digital technology in daily farming practices. Other than political/economical issues, one of the reasons mentioned by several farmers in informal interviews is related to the cumbersomeness of using disintegrated social-media applications to fulfill their farming demands. Moreover, they mentioned that they are interested in the availability of a dedicated smartphone-based agricultural application (or a device) that can fulfill their core needs regarding daily farming practices. Therefore, this research work is aimed to investigate the following research question.

Research Question: Whether the degree of farmers' satisfaction towards the adoption of digital technologies will be improved with the usage of dedicated smartphone-based application (or device) than using

Table 1. Digital Agriculture Applications based on UCD Methodology

Agri. Application Name	Description
AgriAG [21]	Mobile application for streaming and displaying 3D maps of farm agriculture data
CropSAT [22]	Agricultural decision support system developed for the calculation of variable rate application files for nitrogen fertilisation from satellite images.
LMTool [23]	A prototype seasonal climate service for land manager
visualizeR [24]	R-Language package aimed at the provision of actionable climate information through close collaboration with end users.
Mission LQ [10]	A crowdsourcing Precision Agriculture platform (Android, iOS, Desktop versions) developed to teach people how to classify certain characteristics of Lambsquarters
Agro App Mali [25]	Android-based mobile application for farmers to get information about farming activities (Seed, pesticide, fertilizer availability)

social-media mobile applications for realizing routine farming practices.

Based on this research question, the following hypotheses were developed.

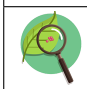
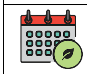
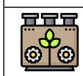
Hypotheses:

H_0: The degree of farmers' satisfaction with the dedicated device or mobile application will not be improved compared to using social-media mobile applications for the realization of digital farming practice.

H_A: The degree of farmers' satisfaction with the dedicated device or mobile application will be improved compared to using social-media mobile applications for the realization of digital farming practice.

Therefore, the primary goal of this research work was to gauge farmers' acceptability of a dedicated smartphone-based agricultural application (or a dedicated device). For this purpose, we developed prototypical interfaces of our proposed AgFAB (Farming-centered Agricultural Bower) application (device) solution as shown in Figure 2 and Figure 3, respectively. The development of these interfaces is based on formal and informal interactions with farmer communities to understand their core requirements from computing devices or smartphone-based applications. Thus, the interface design includes the features mentioned as core demands by the farming community for their daily farming practices i.e., current weather, (extreme) weather forecast, availability and market prices for agricultural commodities (including seed, fertilizer, pesticide), scheduling of farm activities (irrigation, herbicide, and pesticide spray), detection, identification of crop diseases and pest, and cost analysis. Because the farming community was not well-educated, therefore we used specific icons relevant to their core demands. Table 2 provides a description of icons that are used as tangible and intangible buttons in AgFAB device/application. Moreover, it is important to mention that for interface development, we followed the UCD computing approach proposed in [26]. The central idea behind the iterative UCD approach is that the user remains a central entity in the design process from beginning to end and provides feedback at all stages of the design process.

Table 2. Icon Description

Icon	Description
	For weather forecast
	For Disease/Pest Identification
	To Set/View Farming Schedules (e.g. Irrigation, Pesticide, Fertilizer)
	To Check Cost/Profit Margin
	For Sale/Purchase Markets of Agricultural products

4. Evaluation

The following steps have been taken to check the validity of our hypothesis.

Independent Variable (IV): Dedicated smartphone-based agriculture application/device and Social-media mobile applications.

Dependent Variable (DV): Farmers' satisfaction with the application/device prototypical interfaces measured by the SUS (System Usability Scale) score.

Participant Recruitment: The participants in this study were farmers from Burewala city of Punjab province in Pakistan. Taking into account the general consideration of systems' usability research (that demands at least 18 users to identify the problem that impacts $\geq 10\%$ of discovered users while having 85% chance of seeing them in a usability test [27] [28]), in total 20 farmers had been selected over a period of 2 months that shows the fulfillment of minimum recommended sample size.

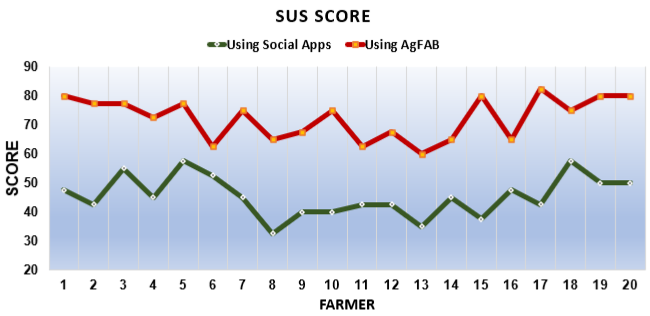


Figure 4. SUS Score of Both Scenarios

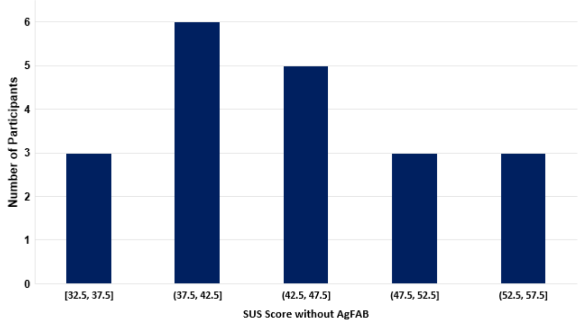


Figure 5. Histogram of SUS Score (without AgFAB)

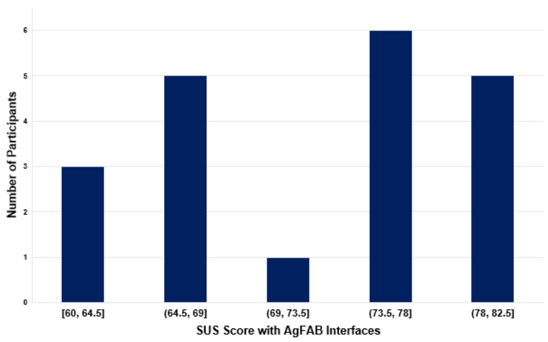


Figure 6. Histogram of SUS Score (with AgFAB)

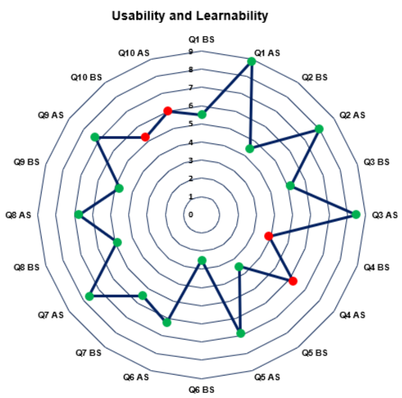


Figure 7. Comparison of Usability and Learnability Scores

Hypothesis Testing: Regression analysis, Analysis of Variance (ANOVA), and Student's t-test analysis are commonly used hypothesis analysis methods. Regression analysis and ANOVA are normally used for continuous data and for comparing more than two groups, respectively. Student's t-test focuses on two group values and due to this fact T-Test had been used for hypothesis testing. The participants were logically split into two dependent groups, Group 1 (G1) and Group 2 (G2). At first, the farmers in G1 were asked to perform their required daily farming activities using different social-media applications on their smartphones. During the second phase, considering exactly the same core features and functionalities, the same group of farmers (logically the G2) had been provided prototypical interfaces in the form of an integrated dedicated smartphone-based application/device. Both of these phases last for 7 weeks i.e., G1 farmers' output was collected in 3 weeks and G2 farmers took 4 weeks to provide their satisfaction score. For the scientific evaluation of farmer's satisfaction in these two experiments, the standard version of SUS [29] [30] was used. Through the statistics of a total of 40 questionnaires, we collected farmers' responses and evaluated their satisfaction using standard formulae (Equation (1) and Equation (2)) associated with the calculation of SUS score.

$$Score = \sum_{i=1}^{10} R(i) \tag{1}$$

$$R(i) = \begin{cases} (Q_j - 1) * 2.5 & \text{if } _j \text{ is Odd;} \\ (5 - Q_j) * 2.5 & \text{if } _j \text{ is Even;} \end{cases} \tag{2}$$

Where *R(i)* and Q_j stand for response of user *i* (where *i≤20*) to question *j* (where *j≤10*), respectively. The satisfaction score of both scenarios has been shown in Figure 4. Figure 4 clearly depicts that farmers are more satisfied after having experience with AgFAB prototypical interfaces. The average SUS score of prototypical interfaces of AgFAB was 72.37 which indicates the acceptability of design and perceived ease of application use. Histograms of SUS scores are shown in Figure 5 and Figure 6. Although, the fundamental motivation SUS was intended to measure the usability; however, it also supports the aspect of learnability that is evident from *Question no. 4* (I think that I would need the support of a technical person to be able to use this system) and *Question no. 10* (I needed to learn a lot of things before I could get going with this system). In general, it is observed that learnability score is higher than usability but we have observed opposite in the case of AgFAB as shown in Figure 7. In Figure 7, Q_jBS

Table 3. Statistical Values of Obtained Results

Name	Value
Mean of Differences	-27
Standard Deviation of Difference	8.17

Table 4. T-test Parameters

Name	Value
Degrees of Freedom	19
Users	20
t-Value	14.8

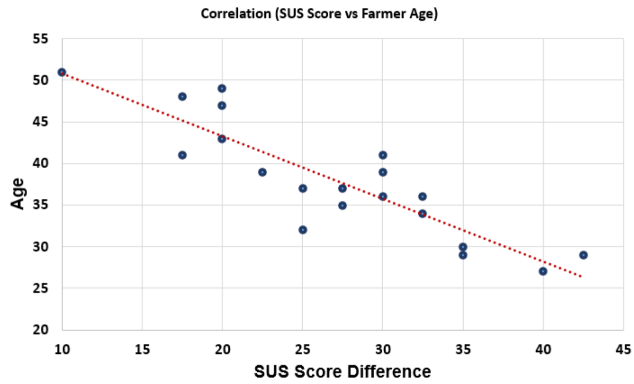


Figure 8. Correlation between SUS Score and Farmer's Age

and Q_jAS representing score values of SUS Questions (Where j ranges from 1 to 10) before and after using AgFAB. Figure 7 shows the small difference of values for Question no. 4 and Question no. 10. The few obvious reasons for this low score can include factors of education level, technology-awareness, and age of farmers. The correlation between calculated SUS score difference and farmers' age shown in Figure 8 indicates that understanding about the usability of AgFAB is higher in young farmers. Moreover, we calculated the mean and standard deviation of sample differences (values are shown in Table 3) of both usability scenarios which were ultimately used for hypothesis testing to determine the significance of the proposed solution. Considering the nature of this study (having the satisfaction score from the same group of farmers before and after the realization of AgFAB working), Paired T-Test was used to determine if there is a significant difference between the means of observations. We used mean and standard deviation values of sample differences in the formula (shown in Equation (3)) to calculate the Paired T-Test statistic (t-value).

$$t = \frac{\bar{X}_{diff}}{S_{diff}/\sqrt{n}} \quad (3)$$

Where
$\bar{X}_{diff}$ = sample mean of the differences,
S_{diff} = sample standard deviation of the differences,
n = sample size (i.e. number of pairs).

This calculated t-value (shown in Table 4) is then compared against a value obtained from a critical value table called the T-distribution table. The higher value of the calculated t-score (14.8) than the obtained critical value (1.729) with the degree of freedom 19 and p=0.05 indicates that a large difference exists between the two sample sets. In terms of Paired t-test, it means that both observations before and after the usage of prototypical interfaces are significantly different and there is a need to develop a dedicated mobile application (device) covering the core requirements of farmers in developing countries. In other words, we rejected the null hypothesis and accepted the alternate hypothesis that the degree of farmers' satisfaction with dedicated mobile applications (or devices) would improve farmer satisfaction compared to the usage of social-media mobile applications for required daily farming practices.

5. Conclusion

The main objectives of this study were related to 1) the investigation of farmers' core demands from digital agriculture applications and 2) the evaluation of their acceptability for a proposed farmer-centered digital agriculture solution (named AgFAB). Considering the farming community's core expectations i.e., weather forecast, availability of market prices for agricultural commodities including seed, fertilizer, pesticide, machinery, scheduling of events, etc. from digital agriculture applications, prototypical interfaces of proposed AgFAB were designed and developed using a farmer-centered approach. These prototypical interfaces were evaluated by the farming community of a developing country. The SUS and T-test score advocates the significance and farmers' acceptability for AgFAB realization over prevailing solutions. Based on these prototypical interfaces, in the future, we are interested to develop AgFAB as a smartphone application to facilitate the farming community of the developing world. Moreover, to address the issues of the old-age farming community, we are inclined to explore the possibility of multi-model applications/devices with haptic and/or aural feedback mechanisms.

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