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Technology Acceptance Model (TAM) - Based Assessment of User Acceptance for a Smart Crop Management System

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ABSTRACT

A smart system that can monitor critical growth parameters and control irrigation and fertilizer applications for tomato production was developed to answer the need for a better and data-driven farm management. The technology was then introduced to tomato farmers in one of the project sites. Technology Acceptance Model (TAM) was used to assess the receptiveness of the farmers to the developed technology focusing on two (2) key predictors: perceived usefulness (PU) and perceived ease of use (PEU). A questionnaire based on TAM principles was formulated for a self-administered survey to assess participants' perceptions and opinions about the developed technology. The reliability of the questionnaire was validated using Cronbach's alpha with a value of 0.93 and 0.96 for PU and PEU, respectively. The PU and PEU scores were found to be 94.83% and 88.41%, respectively. The PU score classified the developed technology as very useful while the PEU score categorized it as very easy to use. A Pearson correlation test was also conducted to investigate if there is a linear relationship between PU and PEU. Results showed that there is a statistically significant positive linear relationship between the two predictors. Several issues were pointed out during the conduct of the technology demonstration that might affect the perception of the farmer group towards the developed technology. Nonetheless, it was concluded that the farmers are indeed receptive and interested with the technology, and their appreciation of the benefits it entails to their livelihood is evident.

Keywords: Internet of Things, smart agriculture, TAM, technology acceptance

INTRODUCTION

To address issues on food security amidst the agricultural impacts of climate change and population growth among others, the Philippines has initiated the adoption of smart farming techniques. The advancement of technologies such as the Internet of Things (IoT) and big data management have played a crucial role in driving precision agriculture forward, as they have provided enhanced capabilities for data collection, management, and communication protocols (Brown, 2018).

In the case of tomato production, losses due to farm management inefficiencies were one of the problems observed in a prior needs assessment and technology intervention studies conducted. Particularly, inefficiencies in irrigation and fertilizer application were observed to be major problems in tomato production. This prompted the development of a smart system that can monitor critical growth parameters and control irrigation and fertilizer applications for tomato production. The system underwent several laboratory and field experiments, until a sensor and actuator network prototype were developed and eventually introduced to tomato farmers.

Technology introduction, albeit a good initiative, may pose certain challenges, especially in farm production where the majority of the employed practices are manual and traditional. To ensure that the developed technology will serve its purpose and provide the intended benefits to the end-users, developers must understand and evaluate the receptiveness and appreciation of the beneficiaries to the said technology.

The Technology Acceptance Model (TAM), developed by Fred Davis in 1986, is one of the most influential theories in understanding user adoption of technology. The model suggests that the primary factors influencing an individual's inclination towards utilizing a particular technology are their perceived ease of use (PEU) and perceived usefulness (PU). These factors subsequently contribute to their attitude toward the technology, ultimately resulting in their intention to use it (Davis, 1986).

TAM is one of the most widely used model in the field of information systems and technology development. Several research and development studies in agricultural mechanization and technology have applied TAM's principles in their adoption assessment. For instance, a study by Läßle & Sirr, G. (2019) utilized TAM to investigate factors that influence farmer adoption of a nutrient plan for precision agriculture. An empirical study by Li, Fu, & Li (2007) also used TAM in evaluating factors that affect the adoption of a mobile commerce in agriculture. In the Philippines, a study of examining factors influencing Filipino farmers' adoption of precision agriculture technologies was conducted and found out that PEU and PU significantly impact's farmers' receptiveness to adopt such technologies (Nguyen et al., 2022).

For this study, the main objective was to explain and demonstrate the whole system to a particular farmer group of interest and assess their receptiveness to the technology. Specifically, the study aimed to:

1. Formulate a questionnaire based on the Technology Acceptance Model (TAM) with Perceived Usefulness (PU) and Perceived Ease of Use (PEU) as the predictors;
2. Identify a farmer group involved in tomato production and conduct technology demonstration activities;
3. Collect data through a self-administered questionnaire to assess participants' perceptions and opinions about the developed technology; and
4. Conduct statistical analyses on the data and interpret based on TAM principles

METHODOLOGY

System architecture

To have an overview of the developed technology, the system architecture and components must first be introduced. The network architecture is shown in **Figure 1**.

The nodes communicate with each other via long range wide area network (LoRaWAN) protocol, and

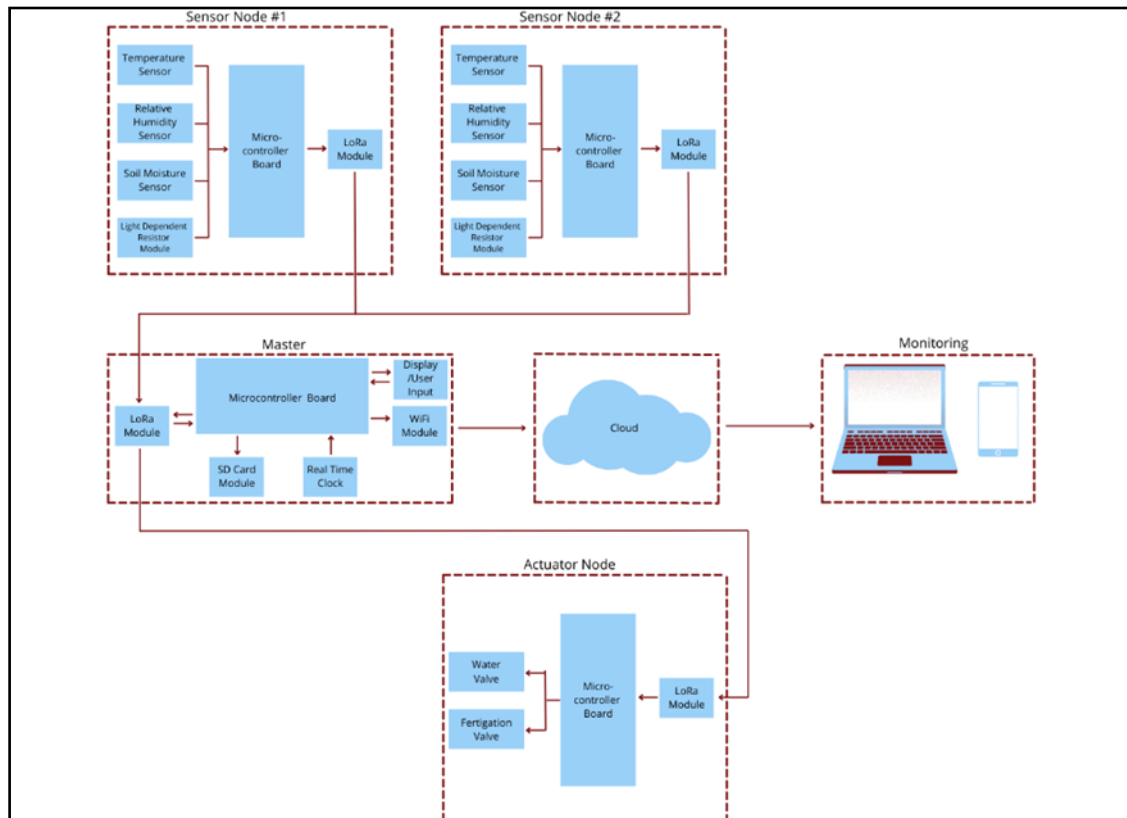


Figure 1. System architecture.

the data is uploaded to the cloud via wireless fidelity (wi-fi). The master requests data from the sensor nodes every 15 minutes and sends commands to the actuator nodes at pre-defined times. The received sensor data is stored locally and uploaded to the cloud to be monitored via a third-party application programming interface (API).

System Components

Sensor pole

The materials used for the frame are $\frac{3}{4}$ " to 1" diameter PVC pipes with $\frac{1}{8}$ thickness which allows for flexibility in terms of assembly options. The housing for the environmental variable sensors is 3D printed using white Acrylonitrile Butadiene Styrene (ABS) filament and a fine printing profile. The housing design which allowed for aeration, is made of inclined threaded circular plates for bonding-agent-free and flexible assembly. A semi-transparent cover sealed with epoxy resin is placed on top to allow considerable amounts of light to pass through.

The housing used for the control unit was an IP65 NEMA4 weatherproof enclosure made of ABS plastic.

Drip System

The housing for the control unit was 3D printed using white ABS filament and a fine printing profile. Two 12V, $\frac{1}{2}$ " NPS solenoid valves were used for both irrigation and fertigation switched by a two-channel SPDT 5V relay module controlled by an Arduino MKR WAN 1310 board.

Master node

The housing used for the control unit was an IP65 NEMA4 weatherproof enclosure made of ABS plastic. The master node was comprised of three microcontroller boards: Arduino Mega 2560, ESP8266 module, and Arduino MKR WAN 1310.

Technology demonstration

A local farmer group was invited for a technology demonstration. Since the system is in its developmental stage, it was intended for it to be exposed first to a specific farmer group. These farmers are considered as early adopters of the technology. Even with a limited number of respondents, a technology acceptance study would still impose significant benefits from targeting early adopters for variety of reasons as long as certain expectations are met. First, the early adopters must be willing to be recipients of technology interventions incorporated into their operation. The selected farmer group is also expected to provide crucial insights into the developed technology based on their experience and identify potential challenges hindering its adoption. These feedbacks allow further refinement of the technology before rollout to broader target users. The farmer group must also be a representative of a broader target audience for the TAM study to be valid for future users. This can be ensured by selecting an experienced farmer group in terms of knowledge and involvement in high-value crop production, particularly in tomatoes. Certainly, it is an intention to conduct further TAM studies for a wider range of farmers.

The farmer group was situated in one of the project sites where the developed system was deployed. The project team first showed the actual deployment of the system and real-time operation. The event then proceeded with a step-by-step demonstration which started by explaining how the system works, and then demonstrating how to operate it using the graphic user interface (GUI). The cloud dashboard was also shown for real-time data access using their smartphones through an internet connection.

Aside from the introduction of the system per component and actual technology demonstration, the participants were also given the opportunity to navigate the system through its graphic user interface (GUI). Quick response (QR) codes were also provided, which redirected the participants to the cloud dashboard where they viewed real-time data that was transmitted by the deployed sensors in the field. Some photos during the technology demonstration are collated in **Figure 2**.

User acceptance

This part of the study aimed to investigate the factors influencing technology acceptance using the Technology Acceptance Model (TAM), focusing on



Figure 2. Photos from the technology demonstration.

two (2) key constructs of TAM: perceived usefulness (PU) and perceived ease of use (PEU) as predictors. This was participated by a total of 31 farmers in the project site who attended the technology demonstration. Participants were provided a questionnaire illustrated in **Tables 1** and **2** for PU and PEU, respectively. Data were collected and analyzed to investigate the extent to which PU and PEU predict the intention to use the technology.

The level of acceptance and reception of farmers with the technology was measured according to the Technology Acceptance Model, using two predictors: PU and EU. The questions in Tables 1 and 2 were formulated following the guidelines based on TAM principles. For the PU, questions were intended to gauge how much participants believe the technology will improve their work or personal life while for the PEU, the questions were intended to assess how easy participants believe it will be to learn and use the technology. A TAM score was computed per predictor consistent with

the system usability scale (SUS) and usability metric for user experience (UMUX) related metrics, where PU and PEU scores were set into a 0–100-point scale. This was done by using the following equations (**Equations 1** and **2**):

$$PU = (AVERAGE(Q1, Q2, Q3, Q4, Q5, Q6) - 1) * \left(\frac{100}{6}\right)$$

Equation 1

$$PEU = (AVERAGE(Q7, Q8, Q9, Q10, Q11, Q12) - 1) * \left(\frac{100}{6}\right)$$

Equation 2

where Q is the question or item number in the questionnaire (Lewis, 2019). These TAM scores were categorized based on their usefulness and easiness.

To validate the reliability of the predictors and the questionnaire, Cronbach's alpha (α) was computed to assess how well the questions were measuring the same factor (Tavakol & Dennick, 2011). If the questions are highly correlated, the Cronbach's alpha value will be high. This implies the strong interrelatedness of the questions used per predictor. Hence, Cronbach's alpha indicates the reliability of the questionnaire by getting similar results while administering the test to the group of people involved (Tavakol & Dennick, 2011). The Cronbach's alpha was computed using the **Equation 3**:

Table 1. Questionnaire for perceived usefulness (PU).

PERCEIVED USEFULNESS (PU)	EXTREMELY DISAGREE <i>Hindi sumasang-ayon</i>						EXTREMELY AGREE <i>Sumasang-ayon</i>
	1	2	3	4	5	6	7
1. Using the technology in my job will enable me to accomplish tasks more quickly <i>Mas mapapabilis ng teknolohiyang ito ang aking trabaho</i>							
2. Using the technology would improve my job performance <i>Mas magagampanan ko nang mabuti ang aking trabaho gamit ang teknolohiya</i>							
3. Using the technology would increase my productivity <i>Mas magiging produktibo ako gamit ang teknolohiyang ito</i>							
4. Using the technology would enhance my effectiveness on the job <i>Mas magiging epektibo ako sa trabaho gamit ang teknolohiyang ito</i>							
5. Using the technology would make it easier to do my job <i>Mas mapapadali ng teknolohiyang ito ang aking trabaho</i>							
6. I would find the technology useful in my job <i>Kapaki-pakinabang ang teknolohiyang ito sa aking trabaho</i>							

Table 2. Questionnaire for perceived ease of use (PEU)

PERCEIVED EASE OF USE (PEU)	EXTREMELY DISAGREE <i>Hindi sumasang-ayon</i>						EXTREMELY AGREE <i>Sumasang-ayon</i>
	1	2	3	4	5	6	7
7. Learning to operate the technology would be easy for me <i>Madali ko lang matututunan ang paggamit ng teknolohiyang ito</i>							
8. I would find it easy to get the technology to do what I want it to do <i>Madali para sa akin gamitin ang teknolohiyang ito ayon sa gusto kong mangyari</i>							
9. My interaction with the technology would be clear and understandable <i>Malinaw at maiintindihan ang aking pakikipag-ugnayan sa teknolohiyang ito</i>							
10. I would find the technology to be clear and understandable <i>Malinaw sa akin at naiintindihan ko ang teknolohiya</i>							
11. It would be easy for me to become skillful at using the technology <i>Mabilis lang akong maging magaling sa paggamit ng teknolohiyang ito</i>							
12. I would find the technology easy to use <i>Madali lang sa akin ang paggamit ng teknolohiya</i>							

measured in $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, light intensity in lux, ambient temperature in $^{\circ}\text{C}$, and relative humidity as well as gravimetric soil moisture content both measured in %.

The MKR WAN 1310 board was used to request data from sensor nodes and send commands to the actuator node (drip system). The ESP8266 module took care of data uplink and local storage. The module sent data processed by the master node (**Figure 4**) to the cloud for the online dashboard via ThingSpeak platform (**Figure 5**).

$$\alpha = \left(\frac{k}{k-1} \right) \left(\frac{s_y^2 - \sum s_i^2}{s_y^2} \right) \quad \text{Equation 3}$$

where α = Cronbach's alpha
 k = number of questions
 s_y^2 = sample variance
 s_i^2 = individual variance

In addition, a Pearson correlation test was conducted to understand if there is a linear relationship between PU and PEU and know its strength and direction if there indeed exists.

RESULTS AND DISCUSSIONS

Walk through of the system

A sensor pole (**Figure 3**) was developed to monitor the following critical growth parameters: photosynthetic photon flux density (PPFD) which is

The ThingSpeak dashboard is comprised of two channels. On channel 1, the values for temperature, relative humidity, and soil moisture are displayed on time series graph widgets while on channel 2, the values for light intensity and PPFD were also displayed on time series graph widgets. Moreover, an additional geotagging widget is found at the bottom of every channel. The channels were updated every time new data was sent to the master node.

Participants' demographics

The selected farmer group for this study was composed of members of the Jasaan – Oogong Farmers Association, a farmer association recognized by the Municipal Agricultural Office of Santa Cruz, Laguna. The association is composed of experienced farmers in high-value crop production, including tomatoes. Prior communication with the officers of the farmer group revealed that the members are still using traditional methods and equipment for their farm production. Furthermore, it



Figure 3. Sensor poles deployed in the field.

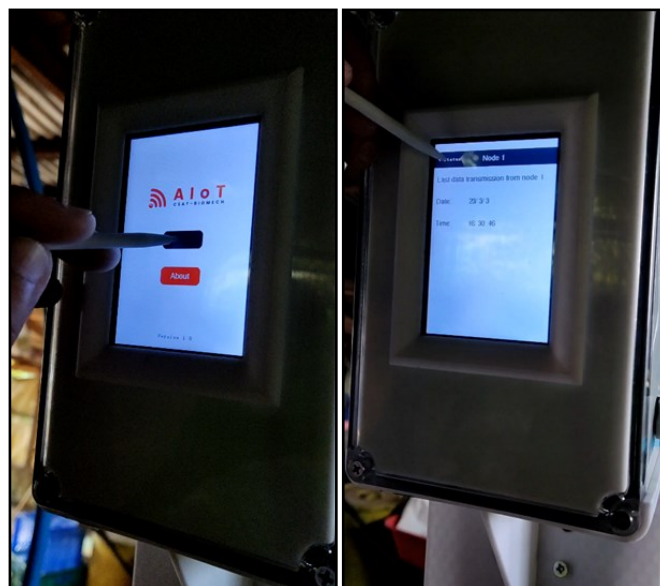


Figure 4. Actual master node GUI located in a secure farmhouse near the actual field.

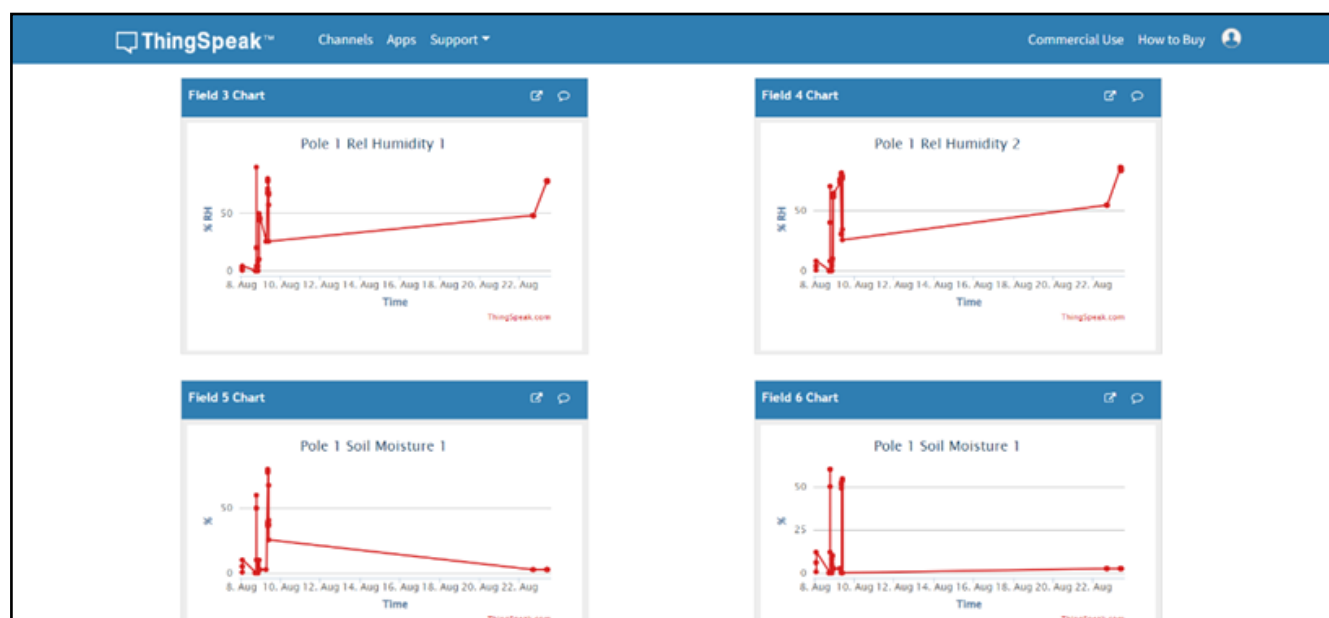


Figure 5. Dashboard snippet.

was also made clear that the farmers were willing to receive technology interventions for their production. In fact, it was pointed out that most of the members indeed seek technology intervention or assistance in their livelihood. A total of 31 participants attended the technology demonstration. Summarized in **Figures 6 to 8** are the demographic data of the participants.

Presented in **Figure 6** are the age groups of the participants. The highest age group was 50-59 with nine (9) participants which was 29% of the total data set. This was followed by the age group 60-69 with a total of seven (7) participants and 22% of the total data set. The 40-49 and 70-79 age groups had three (3) participants each. Lastly, the least age group was 30-39 with only one participant. Five (5)

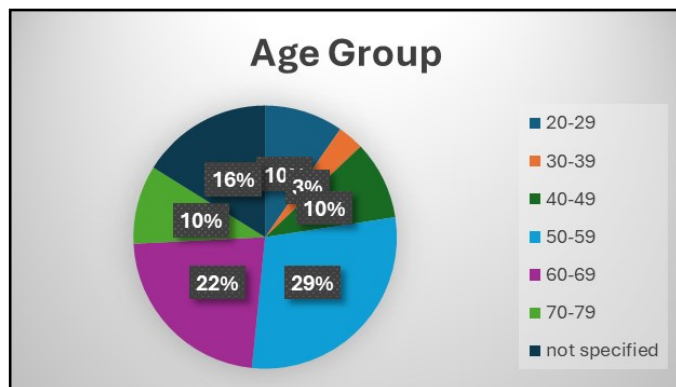


Figure 6. Age group of the participants, n=31.

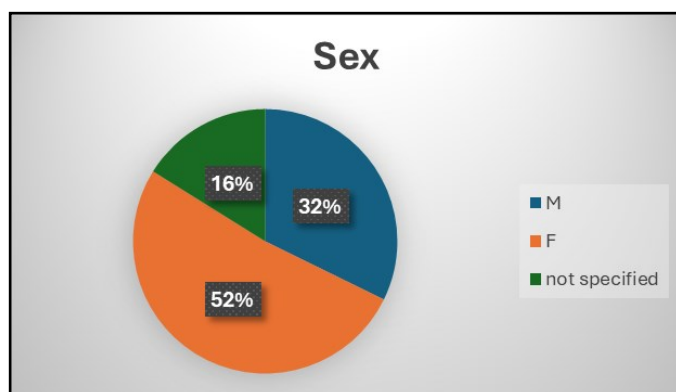


Figure 7. Sex of the participants, n=31.

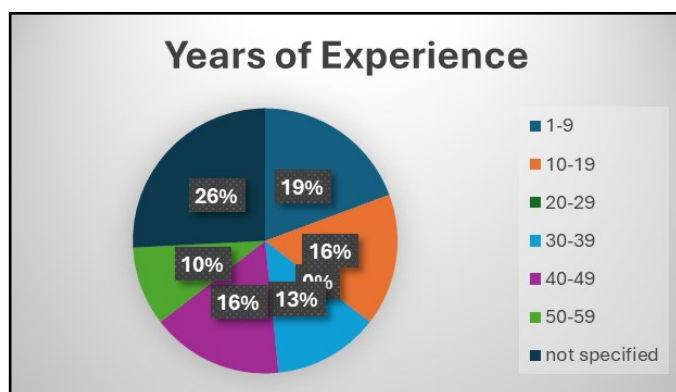


Figure 8. Years of experience of the participants, n=31.

participants did not disclose their age to the researchers. The average age of the participants who disclosed their age was 54.

For the sex of participants, as illustrated in **Figure 7**, it was observed that the majority of the farmers present were females, with a total of 16, or 52% of the data set. Ten (10) participants were male, while

five (5) participants or 16% of the total data set did not disclose their sex to the researchers.

Lastly, for the years of experience, as shown in **Figure 8**, 26% of the total data set did not disclose this information to the researchers. For those who disclosed this information, a total of six (6) farmers had 0-9 years of experience in farming, five (5) had 10-19 years of experience, four (4) with 30-39 years, five (5) with 40-49 years, and three (3) with 50-59 years of experience as a farmer. The average number of years of experience for the participants who disclosed this information was 24.

User acceptance results

PU and PEU scores were computed using **Equations 1** and **2**, respectively. Results from the questionnaire distributed among the participants during the technology demonstration were summarized in **Table 3**. Meanwhile, the categorization of PU and PEU is tabulated in **Table 4**.

The reliability of the questionnaire was also validated using the Cronbach's alpha. As seen in **Table 3**, α values for PU and PEU were 0.93 and 0.96, respectively. There are several qualitative descriptions for the Cronbach's α values, but the general rule is >0.70 is acceptable and >0.90 is best or excellent (Taber, 2018).

As tabulated in **Table 3**, the PU and PEU TAM scores were found to be 94.83% and 88.41%, respectively. Based on the categorization in **Table 4**, the PU score classified the developed technology as very useful while the PEU score categorized it as very easy to use.

The results of the correlation test are summarized in **Table 3**. The null hypothesis, as per a standard correlation test, was that there was no linear relationship between PU and PEU. It can be observed that the T-statistic (t) is greater than the p-value. This means that the null hypothesis was rejected, thereby indicating that there was indeed a statistically significant linear correlation between PU and PEU. For the direction of the relationship, it can be observed that the value of the Pearson

Table 3. Summary of Technology Acceptance Model (TAM) data.

FACTORS	QUESTION #	MEAN	STANDARD DEVIATION	TAM SCORE (%)	CRONBACH'S ALPHA	CORRELATION ANALYSIS		
						T-statistic, t	p-value	r
Perceived Usefulness	1	6.62	0.68	94.83	0.93	0.4806	0.0083	0.4806
	2	6.66	0.61					
	3	6.76	0.44					
	4	6.66	0.55					
	5	6.69	0.47					
	6	6.76	0.44					
Perceived Ease of Use	7	6.38	1.01	88.41	0.96	0.4806	0.0083	0.4806
	8	6.45	1.02					
	9	6.41	0.82					
	10	6.38	1.15					
	11	6.07	1.51					
	12	6.14	1.51					

Table 4. Descriptive categorization for PU and PEU.

PERCENTAGE (%)	PU CATEGORIZATION	PEU CATEGORIZATION
81-100	Very Useful	Very Easy
61-80	Useful	Easy
41-60	Quite Useful	Quite Easy
21-40	Useless	Difficult
0-20	Very Useless	Very Difficult

Source: Arikunto, 2013

coefficient (r) was found to be 0.4806, implying that there was a moderate positive linear relationship between the two predictors.

Results showed that the farmers involved in the demonstration were receptive and interested in the developed technology. The farmers were willing and able to adopt the technology and appreciated the benefits it entails. This is based on the PU and PEU scores of the study. Results also confirmed the validity and reliability of the questionnaire used based on the Cronbach's alpha values of each predictor.

Other observations

Several concerns were raised and pointed out by the participants during the conduct of the study. Since TAM solely focuses on behavioral intention, these feedback were outside the purview of the assessment based on behavior intention. However, those comments that depend on outside factors are

still significant and were mentioned. A TAM-based questionnaire, when complemented by considerations of external factors, offers a robust approach to understanding user adoption of new technologies. These concerns were summarized as follows:

1. Cost – the farmers were concerned if whether they can afford it, or what is the return on investment (ROI) upon incorporating the technology to their production.
2. Security – since the technology is used in an open field, they were concerned about the safety and security of the equipment, especially the sensor poles.
3. Internet access – the cloud dashboard needs internet access both from the area of the master node and the current location of the user upon accessing the data.

CONCLUSION

A smart system that can monitor critical growth parameters and control irrigation and fertilizer applications for tomato production was developed to answer the need for a better farm management in tomato production. The technology was then introduced to tomato farmers in one of the project sites. Technology Acceptance Model (TAM) was used to assess the receptiveness of the farmers to the developed technology.

Results showed that the farmers are indeed willing

(based on Perceived Usefulness score) and able (based on Perceived Ease of Use score) to adopt the developed technology. The reliability of the used questionnaire was also validated using Cronbach's alpha, where it was concluded that the said questionnaire was excellent in terms of reliability. Moreover, it was also observed that PU and PEU have a statistically significant positive linear relationship with each other.

Several issues were pointed out during the conduct of the technology demonstration that might affect the perception of the farmer group towards the developed technology. Nonetheless, it was concluded that the farmers are indeed receptive and interested with the technology, and their appreciation of the benefits it entails to their livelihood is evident.

RECOMMENDATIONS

Since the study was conducted with a targeted group of early adopters, it is highly recommended to conduct further TAM-based studies for a wider range of farmers involved in high value crop production, particularly in tomatoes. More technology demonstrations, trainings, and transfers are recommended to further assess perceptions for the technology of a wider range of farmers. Particularly, once the technical aspect of the system is further developed into accommodating other high value crops, it is recommended to conduct TAM-based studies for a broader target audience. As the technology becomes more widely exposed, user acceptance and perception studies from a wider demographic will be instrumental for a successful adoption.

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The results of this paper were also presented during the 20th International Agricultural Engineering Conference and 73rd PSABE Annual National Convention, and the abstract was included on the Compendium of Abstracts as part of the conference proceedings.

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