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The Acceptability of An Android-Based Rice Black Bug Monitoring System using an Electronic Drone with an Arduino-Based Light Trap

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Abstract: This study aimed to measure the acceptability of an Android-based Rice Black Bug Monitoring System which monitor Rice Black Bugs Bug *(Scotinophara coarctata (Fabricius))*, locally known as *"Itim na Atangya."*, by utilizing an electronic drone with a light trap underneath that records the coordinates and weights of trapped insects. The electronic drone is installed with a high intensity low-energy light-emitting diode (LED) panel or LED-based "black light" to attract rice black bugs which have been reported recently to attack rice crops in southern Luzon. The insect trap is equipped with a weight sensor to monitor the weight of the trapped insects which is used to measure the insect volume. The weight sensor is connected via an Arduino microcontroller board with a built-in WiFi module that connects to a nearby WiFi connection with Internet access to transmit sensed data and GPS coordinates in the online cloud database which can be accessed via a web browser-based application or via the developed Android app for Android-based mobile devices. Through a User Acceptance Test (UAT), the study showed that the designs of both the light trap and the monitoring system have a 3.84 out of 4.0 acceptability rating after evaluated by selected I.T. experts and randomly selected local rice farmers of the Municipality of Catanauan, Quezon where the system was tested, indicating the system has an acceptable quality as a software product and is indicative of readiness for deployment and implementation.

Keywords: android-based rice black bug monitoring system, arduino light trap, electronic drone, rice black bug

1. Introduction

The Philippine government, via the Department of Agriculture (DA), is serious to promote agricultural development by providing the policy framework, public investments, and support services needed for domestic and export-oriented business enterprises.[1] The DA envisions itself as the lead agency of our national government in the agricultural sector of the country to be a competitive, sustainable, and technology-based agriculture and fishery sector, driven by productive and progressive farmers and fisherfolk, supported by efficient value chains and well integrated in the domestic and international markets contributing to inclusive growth and poverty reduction. Having viewed technology as a vehicle towards achieving its goals. This vision of the DA is part of the Philippine Development Plan (PDP) 2017-2022 to empower small farmers and fisherfolk by channeling interventions and investments to expand existing opportunities and develop new ones from different related technologies such as from the computer information and communication field. Part of this development plan is to encourage and promote Philippine local farmers to use and implement sustainable systems and mechanisms in pest management.[2]

The Philippines, being an Asian nation, is a rice-staple country. Being a rice-staple and rice producer country, it needs to empower itself by getting timely and relevant technologies that will improve rice production in the country.[1] Meanwhile, it needs also to implement sustainable rice farming systems in order to ensure a long term crop harvest rate improvement. Part of sustainable farming is the use of alternative systems that would provide a balance in our ecosystem.[3] Among the current trends in sustainable farming is the use of less insecticides which has negative impacts on soil quality, nearby water resources such as rivers, creeks, and streams, and the natural way of encouraging natural pest enemies to do their job in maintaining a balanced insect population. With this, the Philippine Rice Research Institute (PRRI) under the Department of Agriculture, through its official website, warned local farmers to reduce insecticide use in controlling farm pests so as not to kill the natural enemies of crop-friendly insects.[4]

Entomologists Gertrudo Arida and Dr. Hoai Xuan Truong, both from the Philippine Rice Research Institute, named Rice Black Bug (RBB) *(Scotinophara coarctata (Fabricius))*, locally known as *"Itim na Atangya"*, as one of top pests of rice that can damage up to 35% of harvest if not fully managed.[5] Arida and Truong emphasized during the outbreaks of rice black bugs, instead of using insecticides, static light traps could be used 5 days before and after the full moon between 8:00PM to 12:00 midnight through the use of 2,000-3000 watts light bulbs as Rice Black Bugs are attracted to high intensity light. Through this methodology, Arida and Truong further pointed out that the natural enemies of RBB will not be affected or killed, thus, providing a balance in the natural habitat among insects in the rice field.[5]

These information and techniques as well as the mandates and vision of the national government in the agricultural sector is collectively spread with its regional and local government unit counterparts. In the province of Quezon, in which farming and fishing are the main sources of livelihood, the provincial government is maintaining best agro-business practices to ensure that its local farm crops remain viable and sustainable and maintain as the country's leading producer of coconut products and as one of the most important sources of staple food items, such as rice and corn, and vegetables in the Calabarzon region as part of its Comprehensive Agricultural Development Plan of Quezon Province for the years 2011-2019.[6] These provincial goals are distributed down and shared to the Municipality of Catanauan – a 1st class municipality with a population of 71,073 according to the 2015 Philippine Statistics Agency census, and primarily an agricultural town where farm crops like copra, arrow root, bananas, rice, corn, peanuts, garlic, mongo and other vegetables are abundantly harvested.[7]

Recently, an RBB infestation has damaged rice crops and other agricultural plant-based produce of local farmers in Calabarzon, including the Catanauan, Quezon.[8] Although local municipalities in the affected region implement traditional agricultural best practices, they are very much willing to support alternative affordable modern farming approaches and technologies that can improve the growth and development of its local farmers and intensify farm crop harvest rate through responsible and sustainable farm pest management without much effect in the biodiversity of insects and plants and without further burden on part of local rice farmers who are finding it difficult to install electrical cables to nearest electrical outlets just to setup a traditional light trap to their rice fields.[8]

The utilization of the proposed design of RBB monitoring system through the use of electronic drone in which LED-based light trap is installed, these common problems encountered by local farmers and government agencies in dealing with rice black bug infestation can be alleviated and improve pest management methods.

2. Related Works

2.1 Light Trapping as an Alternative Rice Black Bug Control Mechanism

Insect traps are used to monitor or directly reduce populations of insects or other arthropods by typically using food, visual lures, chemical attractants and pheromones as bait and are installed so that they do not injure other animals or humans or result in residues in foods or feeds. Visual lures use light, bright colors and shapes to attract pests and that insect traps are sometimes used in pest management programs instead of pesticides but are more often used to look at seasonal and distributional patterns of pest occurrence.[9]

There are three categories of insect traps based on how insects live on their environments. These are flying insect traps, terrestrial arthropod traps and aquatic arthropod traps.[9]

Flying insect traps can be either adhesive traps where an adhesive substance is applied on a flat panel, which catches bugs once they blunder into them while wandering or exploring, and light traps which attract insects with the use of light sources which include fluorescent lamps, mercury-vapor lamps, black lights, and light-emitting diodes or LEDs.[10] Light traps are used not only to monitor insect population but also as means of farm crop pest control.[9]

Among the insects that are attracted to high intensity light sources are Rice Black Bugs.[10] which is one of the most difficult pests to manage which attacks rice plants in the irrigated area at almost all stages of its growth, particularly from maximum tillering to ripening stage and that damage by this pest could result in severe to complete crop loss during heavy infestation.[5]

Rice black bug nymphs and adults usually stay at the base of the plant during the day and move up to the leaves at night, except when the population is high on which rice black bugs stay at the leaves even during daytime.[5] PhilRice emphasized that light trapping can be used to manage these pests instead of using strong chemicals during times when rice is already a standing crop, during outbreaks, and during harvest times.[4]

During times when rice plant is already considered a standing crop, PhilRice advised that light tapping should be done at 2 days before until 3 days after the full moon. However, during outbreaks or harvest time, PhilRice underscored that light trapping should be done every night to obtain the most number of rice black bugs by using high intensity light sources (bulbs or lamps with 2,000 watts to 3,000 watts energy) from 8:00 o'clock in the evening until 12 midnight. PhilRice also advised that light traps should be mounted 5 to 10 meters high above the ground to cover significant reach among bugs.[4]

Finally, PhilRice recommended that trapped rice black bugs be buried underground to prevent eggs and larvae or rice black bugs to survive and spread out.

2.2. Functional Requirements of the System

a. Pre-Flight Data Collection

Pre-flight data collection is one of the most important requirement of any agricultural electronic drone as it provides real-time data from electronic sensors that can be used to decide whether it is safe both for the drone and humans to fly the electronic drone which include temperature, wind speed, and humidity.[11] These three external factors are important to consider before flying any agricultural drone as they have direct impact on the capabilities and performance of the drone. It is noted that high temperature may make drone's rotors and batteries hotter which may cause it to explode or short-circuit while strong winds may hamper the flight of the drone causing too much work for rotors to catch up or even blow away the drone totally causing great extent of physical damage. Meanwhile, since most agricultural drones are not waterproof, knowing if there is high amount of humidity or high chance that rain will occur during flight is as important as keeping the physical safety of each and every part of the drone.[11]

b. In-Flight Data Collection

Electronic drones are being considered as potential monitoring instrument in the field of agriculture that will help researchers gather accurate data and conduct studies efficiently and that among important drone features that are useful for in-flight data collection are high definition (HD) camera, flight stabilizer, and GPS (Global Positioning System).[12] Commonly used high definition cameras are usually action cameras such as GoPro which are mounted underneath the drone through a gimbal and records panoramic videos which are then downloaded and stored after flight. Meanwhile, in a wider scale, drones can be used to inspect damages during calamities, monitor rice fields during crop establishment, and assess real time conditions in areas to be possibly hit by El Niño.[13]

c. First-Person View Functionality.

First-person view or FPV drone function refers to the ability to remotely see in a mobile device what the drone is actually seeing which is different from that of the gimbal-mounted HD camera which captures and records panoramic views and will be able to view after the flight by uploading the recorded video to a computer while an FPV camera provides a real-time view during flight via a through-the-lens (TTL) serial JPEG camera which is lower in resolution.[14] FPV cameras provide lower resolution images because microcontroller boards do not have on-board image processing unit (IPU) and that transmitting high definition images would require larger and heavier device modules which would add to the payload capacity of the drone.[14] Although FPV cameras mounted on drones have lesser image quality, they offer drone pilots the better drone maneuvers.[14]

d. Wireless Communication and Data Transfer

Wireless communication and wireless data transfer are two of the most important elements of electronic drones regardless of its application as electornic drones are driven and maneuvered using remote controls which communicate with the drone through radio waves.[15] Aside from the use of remote control as means of electronic drone communication, other means of wireless communication can be embedded in a drone to enable wireless data transfer such as WiFi, Bluetooth, and GSM or SMS technologies. Among these three wireless communication technologies, Bluetooth has the shortest range, while WiFi has mid-range and offers secured communication, and lastly, GSM technologies enable communication as long as there is a telecom network available but entails additional cost per messaging.[15]

2.3 Non-Functional Requirements of the System

a. Efficiency

Electronic drone monitoring device efficiency as the ratio of the capability of the drone to perform its basic and advanced functions at a given period of time over some amount of resources such as battery, manual labor, or cost of drone purchase and maintenance.[11] An agricultural electronic drone monitoring device is efficient if a) it has monitored a large area of the farm over the span of its battery capacity per minute; b) if it has performed in shorter time than that of the time it would take for manual labor or task; and c) if the task performed by the drone is cheaper overall as compared to its purchase price and maintenance cost.[11]

b. Durability

Farm monitoring devices should have the ability to remain functional, without requiring excessive maintenance or repair, when faced with the challenges of normal operation over its design lifetime.[16] Parts and components of farm monitoring devices should be of high quality in order to achieve maximum durability.[16]

c. Stability

Stability as a non-functional requirement refers to the consistency of the software or computerized system over time to run properly and will not need per-usage code changes or modifications to achieve proper functioning.[17] Embedded software such as those firmware and libraries of electronic drones need to be reprogrammed every time they are used or run.[17]

d. Usability

Usability is the ease of use and learnability of a human-made object such as a tool or device.[17] In software engineering, usability is the degree to which a software can be used by specified consumers to achieve quantified objectives with effectiveness, efficiency, and satisfaction in a quantified context of use.[14]

2.4 Acceptability of the System

The last test action before deploying and implementing a software is to test its acceptance among its stakeholders with the main goal of analyzing if the software is ready to be used and can really perform the tasks and functions it is created for.[18] There are three strategies to test acceptability: formal acceptance, informal acceptance or alpha test, and the beta test. Acceptability test is a "contract" between the developer and the customer in which the conditions and terms of the contract relate to the features and functional requirements of the system.[18]

Acceptability test conforms to the ISO 25010:2011 quality in use by the Standardization International Organization (ISO) model in which an I.T. product or software is acceptable if quality is attributed or can be experienced in using the software.[19]

The official website of the Standardization International Organization, ISO 25010:2011 defines quality in use as the degree to which a product or system can be used by specific users to meet their needs to achieve specific goals with effectiveness, efficiency, freedom from risk and satisfaction in specific contexts of use. ISO website further highlights that the properties of quality in use are categorized into five characteristics: effectiveness, efficiency, satisfaction, freedom from risk and context coverage.

ISO furthermore noted in its official website that Usability is defined as a subset of quality in use consisting of effectiveness, efficiency and satisfaction, for consistency with its established meaning.

3. Methodology

The developmental method of research was used by the researchers. Developmental studies are concerned with the existing status and interrelationships of phenomena and changes that take place as a function of time.[20] The developmental method of research is used by the researchers in planning, designing, creating, and testing of the rice black bug monitoring system using electronic drone.

The researchers paired the developmental research with the Rapid Application Development (RAD) methodology as its Software Development Life Cycle (SDLC) model. Rapid Application Development is a software development methodology which is used as an approach to building computer systems that combines Computer-Assisted Software Engineering (CASE) tools and techniques, user-driven prototyping, and stringent project delivery time limits into a potent, tested, reliable formula for top-notch quality and productivity[21]. RAD drastically raises the quality of finished systems while reducing the time it takes to build them.[22] Meanwhile, RAD as a methodology enables organizations to develop strategically important systems faster while reducing development costs and maintaining quality.[23]

RAD is designed to ensure that developers build the systems that the users really need. This lifecycle, through its stages, includes all of the activities and tasks required to establish the scope and definition of business requirements and design which can then be used to develop and implement the application system that supports such requirements.[24]

Figure 1 exhibits the overall design of the Rice Black Bug Monitoring System using an electronic drone with an Arduino-based Light Trap. It features the major components of the system which communicates via a router device

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and Internet data connection. These components are the: 1) Pre-Flight Sensors connected to an Arduino Microcontroller board composed of 3 digital sensors that will monitor outdoor/rice farm humidity, temperature, and wind speed; 2) Electronic Drone attached with a global positioning system (GPS) component, first-person view (FPV) camera, high definition (HD) sports/action camera, and a weight sensor connected to another Arduino Microcontroller board; 3) the Rice Black Bug Monitoring Monitoring System Cloud

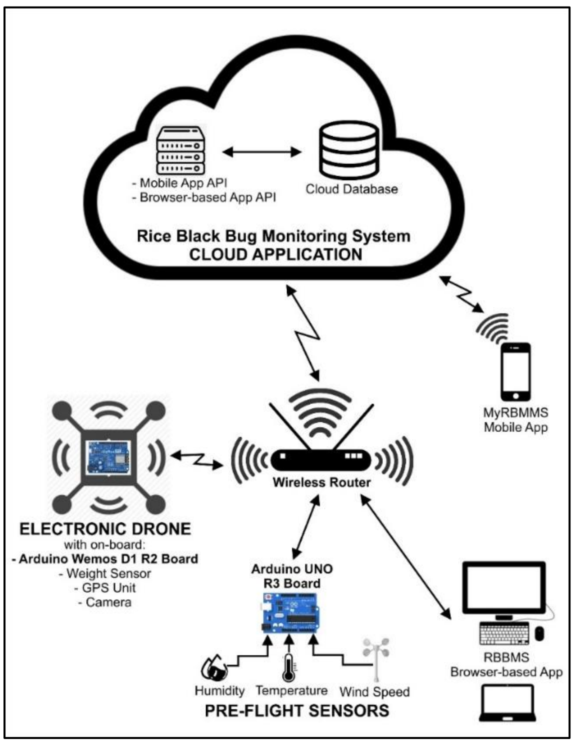

Figure 1. System Design of an Android-based Rice Black Bug Monitoring System Using an Electronic Drone Arduino-based Light Trap

Application that is composed of a Mobile application API, a Browser-based API and the MySQL cloud database; and 4) End User System Interface composed of Web-based browser application interface for desktop or laptop computers and an Android application interface for mobile devices where system end-users can view real-time and historical sensor readings and perform system administrative operations such user account creation and updating and database backup.

The researchers conducted ten (10) demonstration of the device and system attended in group by the two hundred (200) randomly selected local rice farmers of Catanauan, Quezon. The demonstration was scheduled from 8:00 o'clock to 10:00 o'clock in the evening for five consecutive nights, each night composed 2 demonstrations, each from a different barangay. Each demonstration was set to run for only 10 minutes, starting from the time when the black light is lit during drone flight. After the demonstration, each participating local farmer is surveyed to measure the acceptability of the system using a user acceptance test (UAT). The UAT for farmers is composed of 4 criteria as quality indicators. These are: Graphical User Interface (GUI) Design, Usability, Efficiency and Reliability.

Meanwhile, five I.T. experts were also invited and presented to them the developed system. For the UAT to be conducted with I.T. experts, the developers used 8 criteria as quality indicators as prescribed by ISO 25010:2011 Standards which pertains to the quality of software product. These criteria are: Functional Stability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability.

Survey answers from the respondents will be statistically treated using Frequency, Percentage Distribution, and Mean Absolute Deviation.

Frequency refers the number of occurrences of a repeating event per unit of time. It is important in any survey as it directly identifies the quantitative representation of respondents for a particular answer in a survey question.[25]

Meanwhile, percentage distribution or percentage frequency distribution is a display of data that specifies the percentage of observations that exist for each data point or grouping of data points. It is a particularly useful method of expressing the relative frequency of survey responses and other data.[27] The formula for percentage distribution is:

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$$Percentage\ Distribution\ \% = \frac{frequency\ count}{number\ of\ respondents}\ x\ 100\% \quad \textbf{(1)}$$

The researchers used the frequency and percentage distribution formula in order to represent data visually through graphs and chart and identify what percentage among all the respondents is constitute by a certain observation.

Lastly, the researchers utilized Weighted Mean in assessing the system end users rate in terms of the degree of effectiveness, efficiency and satisfaction. The formula for the weighted mean is as follows:

$$Weighted\ Mean = \frac{w_1x_1 + w_2x_2 + \ldots + w_nx_n}{w_1 + w_2 + \ldots + w_n}\ x\ 100\% \quad \textbf{(2)}$$

where w refers to the weights or equivalent to the specified Likert score and *x* represents the set of mean values.

In both UATs, a 1 to 4 scoring is devised, each score representing the degree of agreeability of each criteria/quality descriptor. A score of 4 is equivalent to Strongly Agree (SA) description (DESC), 3 to Agree (A), 2 to Disagree (D) and 1 to Strongly Disagree (SD). A Weighted Mean formula is used to get the total weighted mean of each criteria and the total Weighted Mean (WM) is averaged to get the Overall Weighted Mean which will embody the total acceptability of the developed system.

4. Results and Discussions

Figure 2 showcases the graph of the demonstration weight sensor data which highlights the weight of insects attracted with the black light and the trapped in the electronic drone's light trap for every demonstration conducted in different barangays in five consecutive nights at Catanauan, Quezon.

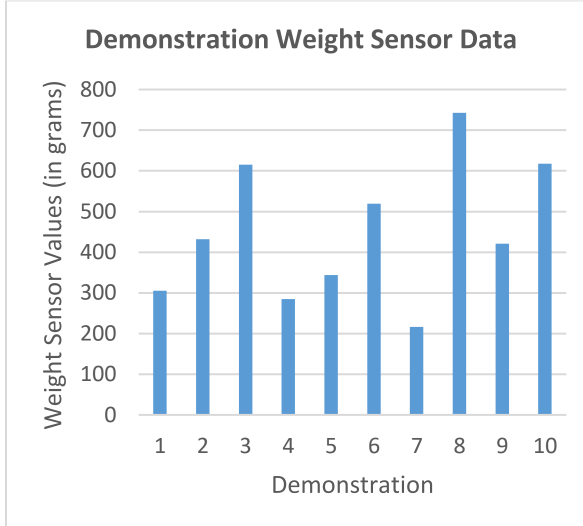

Figure 2. Demonstration Weight Sensor Data

An average of 449.80 grams or almost 500 grams of night insects which are highly attracted to black light composed mainly of rice black bugs were trapped in the electronic drone's light trap, with 743 grams as the heaviest trap value and 216 grams as the lightest trap value. According to local farmers, these demonstration values which were garnered under a 10-minute time frame are far better as compared to their traditional light trap which runs overnight but only traps a considerate volume of insects and not mainly consisted with rice black bugs.

Table 1 exhibits the Summary of User Acceptance Test (UAT) conducted among the two hundred (200) randomly selected rice farmers of Catanauan, Quezon. The overall weighted mean resulted to 3.48 with a description of Strongly Agree indicating that the developed system has an acceptable quality as a software product in terms of graphical user interface (GUI) design, usability, efficiency and reliability.

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Table 1: Summary of User Acceptance Test conducted among randomly selected Rice Farmers

Quality Descriptors	WM	DESC
1. Graphical User Interface (GUI) Design	3.60	SA
2. Usability	3.40	A
3. Efficiency	3.40	A
4. Reliability	3.60	SA
Overall Weighted Mean	**3.48**	**A**

Legend: SA-Strongly Agree (3.50-4.00); A-Agree (2.50-3.49); D-Disagree (1.50-2.49); SD-Strongly Disagree (1.00-1.49); WM-Weighted Mean; DESC-Description;

The 3.60 overall weighted mean for the GUI design with an equivalent description of Strongly Agree indicated that the graphical user interface design of the system embodies an acceptable quality as to the appropriateness, understandability, simplicity, basic functionality of each UI element utilized in the developed system.

Meanwhile, the 3.40 overall weighted means for Usability and Efficiency, with an equivalent description of Agree, shows that, in terms of Usability, the system is usable in its intended real-world application, will yield significant benefits among system stakeholders, can be used in monitoring other varieties of insects in the rice field and that the mobile device Android is easy to use and install without the need for any further technical expertise, and in terms of Efficiency, the developed system is efficient in terms of energy consumption, human resource utilization, microcontroller utilization, internet data bandwidth, and web-browser or mobile app page loading.

On the other hand, the 3.60 overall weighted mean for Reliability, with an equivalent description of Strongly Agree, signifies that the system is reliable in terms of its components providing reliable or calibrated data, computing data according to standardized formula or methods, storing and retrieving, using secured data transmission and storage protocols, and implementing multi-level system user security.

Table 2 exhibits the Summary of User Acceptance Test (UAT) conducted by the five selected I.T. experts. The overall weighted mean resulted to 3.48 with a description of Strongly Agree indicating that the system has an acceptable quality as a software product in terms of functional stability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability.

Table 1: Summary of User Acceptance Test by I.T. Experts

Quality Descriptors	WM	DESC
1. Functional Stability	3.38	SA
2. Performance Efficiency	3.68	SA
3. Compatibility	3.15	A
4. Usability	3.40	A
5. Reliability	3.60	SA
6. Security	3.60	SA
7. Maintainability	3.41	A
8. Portability	3.71	SA
Overall Weighted Mean	**3.48**	**SA**

Legend: SA-Strongly Agree (3.50-4.00); A-Agree (2.50-3.49); D-Disagree (1.50-2.49); SD-Strongly Disagree (1.00-1.49); WM-Weighted Mean; DESC-Description;

The 3.38 and 3.68 overall weighted means for the Functional Stability and Performance Efficiency, respectively, with both description of Strongly Agree, are indicative that in terms of functional stability, the system has functional reliability in terms of having a complete and appropriate core and advanced functionalities and features for monitoring rice black bugs in the rice field, compliance with standardized protocols and objective-based methods, while in terms of performance efficiency, the system has is highly efficient in terms of utilizing minimal number of microcontroller boards, internet data bandwidth other system-related implementation resources.

Meanwhile, the overall weighted means of 3.15 and 3.40 for Compatibility and Usability, respectively, with both description of Agree, suggests that in terms of compatibility, the system is compatible to run among web browsers installed computers with either 32-bit or 64-bit processor architecture, web browsers of mobile devices (either iOS or Android), compatible to transmit data over WiFi form any routers, access points or mobile phone hot spots, and microcontroller devices are compatible to run and be operated using either 110V or 220V power supply, and in terms of usability, the developed system is practically utilizable in its intended real-world application, will yield significant benefits among system stakeholders, can be used in monitoring other varieties of insects in the rice field and that the Android app is easy to use and install without the need for any further technical expertise.

In terms of Reliability and Security, which each garnered a 3.60 overall weighted mean with an equivalent description of Strongly Agree, shows that the system reliable in terms of its components providing reliable or calibrated data, computing data according to standardized formula or methods, storing and retrieving, using secured data transmission and storage protocols, and implementing multi-level system user security, and that the system is secured in terms of its keeping data with high integrity by following data storage and transmission security standards and protocols, implementing multi-level user security controls, and utilizing system logs to document data processing and system user activities.

In terms of Maintainability, the 3.41 overall weighted mean with an equivalent description of Agree implies that the system has an acceptable degree of maintainability as it utilizes modular programming/development that limits faults to particular modules only and does not damage the entirety of the system, test data can be implemented without affecting production-level data, and integration/repair of system units/parts or modules will not cause total system stoppage.

Finally, 3.71 overall weighted mean with an equivalent description of Strongly Agree for Portability is indicative that the system is portable in terms of implementing one APK installer that will work for most Android mobile devices, using the system to other species of insects in other rice farms, and the servicing microcontroller components without affecting other sensors or the entirety of the system.

5. Conclusion

The utilization of Arduino microcontroller boards with built-in WiFi module is an efficient and less expensive means of developing Internet of Things (IoT) devices as it is capable of handling several digital and analog sensors simultaneously. The modernization of rice black bug pest control and management among local farmers will greatly benefit in terms of an alternative modern method of bug control, monitoring and mitigation through the use of an online rice black bug monitoring system as consistently evidenced by the weight sensor readings of the system and through the use of black light.

The Android-based rice black bug monitoring system using an electronic drone with Arduino-based light trap for local rice farmers has an acceptable quality as a software product as evidenced by an overall weighted mean of 3.84, described as Strongly Agree, after evaluated by selected I.T. experts and randomly selected local rice farmers using a User Acceptance Test (UAT) indicating the readiness of the developed system for deployment and implementation.

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