Irrigated Rice Yield projeCtion E-application (iRYCE)

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Abstract--- Using the descriptive and developmental design, the study developed and evaluated an Irrigated Rice Yield projeCtion E-application (iRYCE) to predict rice yield of irrigated farms in Bayombong, Solano, Bagabag and Quezon, Nueva Vizcaya, Philippines. A total of twenty (20) farmer participants with irrigated rice fields adjacent to each other were the respondents from the four municipalities. While forty (40) system evaluators and end users from the academe, DA planning officer, ICT program developer and agriculturist/technician evaluated the proposed iRYCE application. A questionnaire, interviews and observations were conducted from the field practices of the farmers with all the inputs in the conceptual paradigm of this study. The researcher used frequency count and percentage distribution, mean, chi-square, pearson r and linear regression analysis to predict and determine the extent of relationship of projected rice yield with the result of soil analysis, average yield of the participants per annum, rice variety, fertilizer application, number of days of rice seedling before transplanting and harvesting. Dynamic System Development Method Framework was utilized as its guide in the development of the iRYCE application. As a result, Nitrogen nutrient of the soil samples from the four municipalities had a low qualitative description. Phosphorous nutrient test had a qualitative description distributed from low to high and Potassium had a high qualitative description. The municipality of Solano had an average description rating in terms of average yield per annum while the three other municipalities had a descriptive rating of low. The overall rice varieties that were utilized by the farmer participants were RC 222 (45%), RC 226 (25%), RC 216 (12.5%), RC 152 (10%), RC 440 (5%) and RC138 (2.5%). Majority of the farmer participants followed fifteen days (15) after transplanting in their fertilizer application of side dress. While the days before harvesting practice of the farmer participants had a range from 108 to 115 days. Findings showed that the extent of software compliance as evaluated by system evaluators revealed that the proposed system was accepted unconditionally based on ISO 25010 criteria. The results showed that the overall features of the system with respect to ISO criteria were all met.

Keywords: Developed system, Dynamic System Development Method Framework, Soil analysis

I. INTRODUCTION

ICT plays a very important role in precision agriculture. The leading International Rice Research Institute came up with different ICT solutions like the use of a diagnostic tool called the Rice Doctor. It gathers field condition and recommends solutions for better farming practice. The Department of Agriculture together with Philippine Rice Institute developed the Pinoy Rice knowledge bank which is a web enabled system that gives valuable information and solutions to help rice technicians in guiding farmers to have a better yield. Existing and on-going researches about rice aimed to develop high resistant varieties that can withstand

climate change that causes drought, flood, soil erosion and increasing sea level. Some technology assisted solution like the Rice Crop Manager uses the internet and smart devices to recommend strategies and to serve as crop advisor on how to increase yield by on site data gathering from farmer participants. This type of innovation focuses more on the growth of rice through fertilizer application starting from the prescribed days after transplanting (DAT) or days after seeding (DAS) and significant schedules where fertilizer is needed most by the rice plant.

Soil analysis was done by the Department of Agriculture every three years (six cropping) on a provincial level approach where soil samples were collected in sporadic barangays in the different municipalities of Nueva Vizcaya. The result of the data was processed and the results were consolidated forming soil nutrients of Nitrogen, Phosphorous and Potassium (NPK) map in Nueva Vizcaya. However, it

was only a mere representation of a small portion in the rice producing field that form part in the macro representation of soil nutrient stores in some area (NPK) moreover, negative impact of climate change in the environment could also affect soil fertility from time to time due to soil weathering, flood, soil erosion and other factors that would affect soil fertility level in rice lands.

With existing ICT development in agriculture and in relationship to this study, an analogy can be drawn between the role of a general medical practitioner and a medical specialist. The former gathers data by observation and asks relevant data and circumstances related to the medical condition of his client. He may also perform vital procedures like blood pressure and body temperature readings after which he gives his prescription. On the other hand, other than the former's medical procedure, the latter who is a medical specialist digs deeper information on the medical history of the patient and requires blood chemistry to conclude his findings before giving prescription.

It is in this context that the role of a medical specialist must be adopted in this foregoing study and there is a need to focus specifically a priority to conduct soil analysis at least once a year before planting to understand and determine the real soil fertility level along with the field practices of farmers as basis in recommending correct kind and amount of fertilizer for optimum growth and development, and yield of rice. For this reason, this study was conceptualized to develop an Irrigated RYCE application.

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Conceptual Framework

The conceptual framework of this study was adopted on the concept of the Internet of Things (IoT) technology (Zhao, 2010). It was observed that control networks and information network integration of IoT technology will be helpful in the actual situation of agricultural production3. Dar (2016) elaborates that IoT talks of connectivity, precision and networking such that understanding of what works best in a given situation requires a judicious blend of culture and modern technologies1.

By adopting the IoT and using the Dynamic System Development Method (DSDM) for software development framework the researcher came up with the desired irrigated RYCE application.

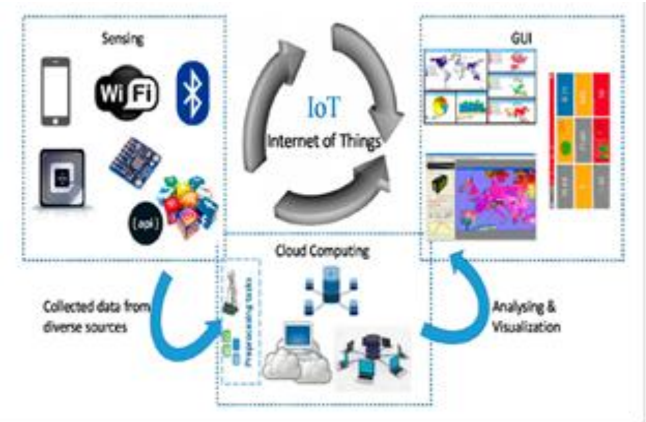

Figure 1. Internet of Things (IoT) (Mora, H. et al., 2017)

Fig. 1 shows a diagram of the Internet of Things that can be adopted in this research study. The sensing stage in this study was conducted by the soil laboratory of the BSWM in analyzing the main nutrient components of soil. Added at this stage will be the collection of data from the farmers' field practices; rice variety including fertilizer application will be considered.

All data inputs will be stored in a cloud computing environment and it could be downloaded per municipality for farmer localization and mapping. With linear regression statistical method, all the data would be analyzed and processed to determine yield projection of rice.

The end process is the visualization stage where the desired output of the system would be projected in a graphical map depicting the output of the iRYCE application.

Statement of the Problem

This study developed and evaluated an Irrigated Rice Yield projeCtion E-application (iRYCE) to predict rice yield of irrigated farms.

Specifically, it sought answers to the following:

1. What is the result of the soil analysis test in terms of:

1.1) Nitrogen content,

1.2) Phosphorous content, and

1.3) Potassium content?

2. What is the average yield of the farmer participants per annum?

3. What are the field practices of the farmer participants in terms of:

3.1) Variety of rice utilized,

3.2) Fertilizer application: basal, first top dress, second top dress and third top dress,

3.3) Number of days of rice seedlings before transplanting, and

3.4) Number of days before harvesting?

4. Is there a significant relationship between the dependent (rice yield) and the independent variables (average yield of the participants per annum, rice variety, field practices: fertilizer application, number of days of rice seedling before transplanting and harvesting)?

5. What linear regression equation can be formulated as basis for the development of the proposed system?

6. What proposed application can be developed utilizing a regression model to predict rice projection yield based on soil fertility level parameters, average yield of the participants per annum, rice variety, field practices: fertilizer application, number of days of rice seedling before transplanting and harvesting?

7. What is the extent of compliance of the developed application in terms of the overall features and system performance and the following ISO 25010 criteria?

7.1) Functional Suitability,

7.2) Reliability,

7.3) Usability, and

7.4) Performance Efficiency?

II. METHODOLOGY

Research Design

The study made use of descriptive survey and research system development to develop and evaluate an Irrigated Rice Yield projeCtion E-application (iRYCE) to predict rice yield of irrigated farms.

Participants of the study

The sample was made up of three groups of participants which totaled to 60 (100%) farmers, system evaluators and end users that composed of ICT experts from the academe, DA planning officer, ICT program developer and agriculturist/technician. They were distributed as follows: Twenty (20) selected farmers from four selected municipalities of Nueva Vizcaya (Bayombong, Solano, Quezon, and Bagabag) with five (5) farmer participants per municipality with irrigated rice fields that are adjacent to each other. A soil analysis was conducted from their respective rice land to come up with NPK soil nutrient result. Likewise, data gathering on farmer's field practices were also collected. Twenty (20) system evaluators were selected to be the participants on the evaluation of the overall features and system performance of the proposed system who are from the academe and ICT program developer and twenty (20) end users were selected to be the participants on the evaluation of the proposed system who are from DA planning officer and agriculturist/technician from the BSWM and Municipal Agriculture Office.

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Instrumentation

The questionnaire that was used for gathering the needed data was subjected to try-out and validation before its field administration. It was used to gather the demographic profile of the farmers, end users and ICT experts as participants in this research study was based on ISO 25010 criteria. An interview and observation were conducted from the field practices of the farmers along with all the inputs in the conceptual paradigm of this study.

The soil samples were subjected to soil analysis test and inputted into the proposed system as one of the dependent variables.

Data Gathering Procedure

Before gathering and collecting data, the researcher sought the proper authorization and permission to conduct research from the Nueva Vizcaya Provincial Agriculture Office and the four (4) Municipal Agriculture from the municipalities of Bayombong, Solano, Bagabag, and Quezon. The request for proper communication protocol was observed in the dissemination of questionnaires to system evaluators and end users.

Data Analysis

The data collected were tabulated, analyzed, interpreted, and summarized using both descriptive and inferential statistics. The data were analyzed using the Statistical Package for Social Science for Windows (SPSS for Windows).

Frequency Count and Percentage Distribution were used to describe the demographic profile of the participants, the variety of rice used, and field practices of the farmer participants.

Mean was used to analyze the average rating of the IT experts with respect to the compliance of the application that was developed in this study in relation to the ISO standard.

Chi-square was used to test for significant relationship between the participants' rice yield and the following variables:

a. Rice variety,

b. Field practices.

Pearson r was used to test the linear correlation between the participants' rice yield and the following variables:

a. Number of days of rice seedling before transplanting,

b. Number of days of rice seedling before harvesting.

Linear Regression Analysis was used to predict and determine the extent of relationship of all variables to come up with a mathematical model that served as the basis in the development of the RYCE application to predict rice yield.

III. RESULTS AND DISCUSSIONS

The ultimate aim of this study was to develop and evaluate an ICT based Rice Yield projeCtion E-application (RYCE) to predict rice yield of irrigated farms based on soil fertility level.

1. Through soil analysis the soil nutrients of the rice field of the farmer participants were known to them. The soil sample gathering was conducted after the first cropping in the municipalities of Bayombong, Bagabag, Solano and Quezon in Nueva Vizcaya.

The result of the Nitrogen nutrient of the soil samples from the four municipalities revealed a low description rating based on the BSWM Nitrogen table.

The result of the Phosphorous nutrient test of the four municipalities had a qualitative description from low to high based on the BSWM Phosphorous table; Olsen test was used due to the high ph content of soil of the four municipalities. As a result, Bayombong had a qualitative rating as low; Solano had a qualitative description as moderately low; Bagabag had a qualitative description as moderately low and Quezon had a qualitative description as high.

Based on the BSWM Potassium nutrient table, all respondent municipalities had a high qualitative description.

2. The average annual yields of the farmer participants from the highest down to the lowest average annual yields in the four municipalities were 99, 70.1, 62, and 52.6 taken from Solano, Quezon, Bagabag, and Bayombong, respectively.

3. The overall rice varieties that were utilized by the farmer participants were RC 222 (45%), RC 226 (25%), RC 216 (12.5%), RC 152 (10%), RC 440 (5%) and RC138 (2.5%).

The fertilizer application of farmers showed that only 19 farmer participants practiced the application of side dress and one (1) neglected to apply side dress. There were twelve (12) farmer participants who utilized 46-0-0, four (4) farmer participants used 16-20-0 and three (3) farmer participants who utilized 14-14-14.

Majority of the farmer participants followed fifteen days (15) after transplanting in their fertilizer application of side dress. There were three (3) farmers who applied both twenty-five (25) and thirty (30) days after planting, while one for each twelve (12) and fourteen (14) after transplanting.

The ratio of fertilizer per bag ranged from 0.33 to 5 bags depending on the area being planted by farmer participants.

The days before transplanting practice of the farmer participants had a range from 15 to 25 days. It could be noted that majority of the participants preferred 15 and 23 days of transplanting with both frequencies of 35%. While the preferred days of the minority farmer participants were distributed almost even from the given range. While the days before harvesting practice of the farmer participants had a range from 108 to 115 days. It could be noted that majority of the participants preferred 114 days having a percentage of 55%. While 108 and 115 days were the least choice of harvesting days by the participants.

4. On the test for linear correlation. The test for significant relationship of linear correlation between yield and number of days before transplanting was not related to the total yield of the farmer, as well as to the average yield per hectare. These findings suggest that total yield and average yield per hectare was not affected by the number of days before transplanting.

While the test for significant relationship between the number of days before harvesting was significantly related to total yield of the farmer and to the average yield per

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hectare. These further imply that lower number of days of transplanting contributed to high yield of the farmer as well as to the average yield per hectare.

There was no association between the rice variety cultivated and the total yield during the first cropping. Similarly, there was no association between the rice variety cultivated and the total yield during the second cropping.

5. Regression analysis was used to analyze and determine the relationship between the response variable and explanatory variable. The independent variables considered for analysis in this research work were soil analysis result, rice variety, field practices like fertilizer application and number of days of rice seedling before transplanting and harvesting. Rice yield was the dependent variable which depended on the independent variables.

The following Linear Regression Equation (1) was derived in the development of the proposed system:

$$Y = 2.044*X_1 - 0.204*X_2 + 1.775*X_3 - 21.479*X_4 + 12.384*X_5 + 33.945*X_6 + 14.632*X_7 + 47.989*X_8 + 0.047*X_9 + 0.401*X_{10} + 4.219*X_{11} + 27.977*X_{12} + 10.198*X_{13} + 47.572*X_{14} + 1.307*X_{15} - 0.799*X_{16} + 2.771*X_{17} + -355.454 \quad (1)$$

Where:

Y = Projected Yield per hectare
X_1 = Phosphorus level of the soil (actual reading)
X_2 = Potassium level of the soil (actual reading)
X_3 = Application of 14-14-14 fertilizer during Basal (1 – yes, 0 – No)
X_4 = Application of 46-0-0 fertilizer during Basal (1 – yes, 0 – No)
X_5 = Total amount of fertilizers per hectare applied during basal (0 – 3.75 bags)
X6 = Application of 16-20-0 fertilizer during Side dress (1 – yes, 0 – No)
X7 = Application of 14-14-14 fertilizer during side dress (1 – yes, 0 – No)
X8 = Application of 46-0-0 fertilizer during Side dress (1 – yes, 0 – No)
X9 = Total amount of fertilizers per hectare applied during side dress (0 – 6 bags)
X10 = Number of days after the transplanting during side dress (12 – 30 days)
X11 = Application of 46-0-0 fertilizer during top dress (1 – yes, 0 – No)
X12 = Application of 14-14-14 fertilizer during top dress (1 – yes, 0 – No)
X13 = Application of 25-0-0 fertilizer during top dress (1 – yes, 0 – No)
X14 = Number of combination of fertilizer per hectare applied during top dress (0 – 2 fertilizers)
X15 = Number of days for the top dress (30 – 45 days)
X16 = Number of days before transplanting (15 – 25 days)
X17 = Number of days before harvesting (108 – 115 days)

As deduced from the coefficients of the regression equation, the practices with the highest contribution to yield per hectare were the following: application of fertilizers 46-0-0 and 16-20-0 during side dress. The application of these fertilizers during the side dress may increase the total yield per hectare as indicated by the Beta coefficients of greater than 33, respectively. The application of 2 to 3 fertilizer during top dress, particularly the fertilizers 14-14-14 and 25-0-0 may likewise increase the total yield per hectare as indicated by the Beta coefficients of greater than 10.

It could also be noted that there was a small association to yield with the levels of phosphorus, application of fertilizer 14-14-14 during basal, number of bags of fertilizers applied during side dress, number of days before the side dress, application of fertilizer 46-0-0 during top dress, number of days before top dress, and the number of days before harvesting.

There was also a negative impact to the yield with the application of fertilizer 46-0-0 during basal, minimal potassium content of the soil, and the number of days before transplanting.

6. The proposed application adopted the derived Linear Regression Equation in the development of the Irrigated RYCE projection application. An android application was also developed for site specific fertilizer recommendation for farmers as a tool for IoT.

7. Findings showed that the extent of software compliance as evaluated by system evaluators revealed that the proposed system was accepted unconditionally.

On the part of the end users, the result of their evaluations based on the ISO 25010 compliance revealed that the system functional suitability and all its sub characteristics were beyond the expectation of the system evaluators and it was accepted unconditionally.

As to the system reliability and all its sub characteristics as assessed by the end users, the results had a qualitative description of accepted unconditionally.

In terms of usability and all its sub characteristics as assessed by the end users, findings showed a qualitative description of accepted unconditionally.

While on the performance efficiency of the proposed system, the end users had a qualitative description of accepted unconditionally.

IV. RECOMMENDATIONS

Based on the findings and the conclusions of the study, the following are strongly recommended:

1. On the NPK soil nutrients. The soil deficiency can be treated by following the recommendation of the Bureau of Soil and Water Management (BSWM) and could be analyzed at least every two cropping to monitor soil nutrient changes and to address corresponding fertilizer pattern schedule and inputs. The Irrigated RYCE App that was developed in this study is a useful tool in downloading site specific fertilizer recommendation for farmers.
2. On the annual average yield. The results of the soil analysis if followed by the farmers can increase their annual yield provided that it would be closely monitored by an agriculturist for proper guidance in the application of the fertilizer pattern schedule and inputs.
3. On Information dissemination. The function of the agriculturist in disseminating information on rice production must be strengthened. A "school in the farm" concept can be adopted to educate farmers to adopt new

rice variety fitted to their environment along with the proper timing and application of fertilizer as recommended by BSWM. By closely monitoring, guiding, and educating farmers, it may increase yield.

4. On the field practices. The fertilizer pattern of the BSWM is highly recommended with the simulation of the linear regression of the proposed system to project rice yield.
5. The farmers should consider the prescribed scientific date of transplanting of every crop variety listed in the rice knowledge data bank to ensure high yield.
6. The developed application can be adopted by farmers with irrigated rice fields provided that they should be required to conduct soil analysis in their respective rice field.
7. The proposed system is adoptable to the Department of Agriculture especially in irrigated rice environment. Since the BSWM has its database of soil analysis results, the system is flexible to adopt the results and automatically be imported to the proposed system as a reference of the different municipalities in the Region.

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