Crop Management System (CMS) for Farm Productivity Maximization for LA Rice Mill

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Abstract: Precision agriculture is an emerging approach to agriculture by focusing on site-specific crop management based on the acquisition, process, and analysis of spatial and temporal data to respond to the inter-field and intra-field changes within the farm. It makes use of information technology such as satellites to gather vast amounts of data that may otherwise not be available for large-scale production. The collection of data allows farm managers to create optimal decisions by ensuring that crops receive input resources based on their specific needs as they rely on environmental variables. The project hopes to produce a solution to problems such as inadequate risk mitigation of natural disasters, inefficient use of resources, and poor decision-making for crop management that result to decrease in yield. The general objective is to develop a Crop Management System (CMS) that can accommodate the data collection requirements of precision agriculture without the implementation of costly IoT devices in the field. The solution aims to provide optimal decisions in rice production, which would both be adaptive and effective to the changing environmental conditions. The methodology used was hybrid (Agile and Kanban approach). Tools and technologies include, MySQL, AgroAPI for satellite imagery and data; Mapbox and OpenStreetMap for the visualization and analysis of geospatial data; SMS technology for the distribution and collection of data; and HTML, CSS, JavaScript, and the Bootstrap Framework for the client side. A user acceptance testing was conducted among the owner and office employees.

Key Words: Farm Productivity; Precision Agriculture; Crop Management System; Geographic Information System; Remote Sensing

1. INTRODUCTION

Climate change in recent years has posed a significant threat to the agricultural crops and practices of smallholder farmers. Due to the volatile nature of climate change, smallholder farmers no longer can rely on ancestral knowledge in the ways they plant and cultivate their crops anymore as this issue is too much for them to handle on their own (FAO, 2017b). They reported that failing to address climate change would lead to decreased food security due to its adverse effects on agricultural yields and livelihoods. Moreover, it is expected that until and beyond 2030, global warming would continue to severely decrease crop productivity and agricultural yields, with tropical developing regions being the most affected. This brings the need to ensure the resilience of smallholder farmers. It will be the key to eradicating global poverty and climate change impacts, which can be achieved by adopting climate-smart practices and technologies (FAO, 2016a, pp. 3-71).

Climate-Smart Agriculture ((CSA) is an approach that uses digital techniques to innovate agricultural systems for promoting sustainable agriculture and food security in the face of climate change. Some ICTs involved in this approach are the internet of things (IoT), remote sensing, and robotics (Adamides, 2020, p. 1). The field of activity that makes use of these ICTs is e-Agriculture, which aims to increase the agricultural productivity of farmers and the availability of agricultural information for the industry's respective stakeholders (Chauhan, 2015, p. 228). An advanced implementation of e-Agriculture is precision agriculture, where farmers utilize technologies to maximize their profits, and productivity in producing quality crops. A common type of technology used for precision agriculture is satellite technology, which not only allows farms to reduce their costs but also improves their yields that promote environmental protection in a sustainable manner. Rains and Thomas (2000, as cited in Okediran & Ganiyu, 2019, p. 128) mentioned that precision agriculture utilizes five technological components: (1) GIS for analyzing and managing spatial data and mapping, (2) remote sensing for identifying accurate data about the environment using satellite technology, (3) GPS for locating and defining spatial activities for site-specific activities, (4) variable-rate technologies (VRTs) for applications that target site-specific inputs, and (5) yield monitoring for providing a crop management database for crop productivity. With this, the study will further explore the CSA approach and the utilization of the ICTs involved with precision agriculture in the conceptualization of their solution.

The Philippines is vulnerable to climate change and variability caused by severe weather-related conditions. This causes farmers to become vulnerable to the adverse effects of these conditions with their inadequate adaptive capacity. In a study that determines the farmers' local adaptation strategies and experiences, results show that farmers understand the severe risks involved in climate change despite their limited knowledge of how it occurs. Furthermore, they recognize that climate conditions changes affect temperature and rainfall, which poses challenges to their water supply. Interrelated impacts such as crop damages, pest infestations, and rice yield loss also put their farming activities at risk. To combat these, they usually employ standard adaptation measures to respond to climate variability, such as planting different crop varieties, using chemical fertilizers and pesticides, utilizing farming technologies, and diversifying household incomes. (Peñalba, 2019, p. 1).

In another study that explored the influences of climate variability on the production and yield of rice of irrigated and rainfed production systems at various scales in the Philippines from 1987-2016, results show that El Niño–Southern Oscillation (ENSO) has dramatically affected rice production through variations in soil moisture during this period. Moreover, they also found that climate impacts on rice production were seasonal and varied per region. Their expectations of rainfed upland rice production systems being highly reactive to soil moisture variability compared to irrigated paddy rice were also confirmed with about 10% of the variance in rice production irregularities co-varying with the changes in soil moisture, which in turn were negatively correlated with ENSO variability. With this, they conclude that while variability in temperatures is currently still considered insignificant in the Philippines today, climate predictions by the end of the century indicate that temperatures may regularly exceed the usual limits in rice production. This brings the need for seasonal forecasts to cater to the relevant information to support agriculture management in reducing soil moisture variability and temperature stress (Stuecker et al., 2018, p. 1).

Another major contributing factor of low productivity in rice production is the suboptimal crop management practices of smallholder farmers. They continue to do practices that fail to consider the proper application of fertilizers, more specifically its correct combination, dosage, and time of application. With this, to achieve rice productivity and efficient use of resources, technologies for crop and nutrient management are required to consider the knowledge-intensive farming and field practices effectively. This, as a result, would lead to higher farm productivity, rice yield, and food security (FAO, 2017a, p. 2).

The objective of the study is to develop a crop management system (CMS) for LA Rice Mill in order to maximize the organization's farm productivity. The study will cover the management and operational functions and tasks of the crop production process of LA Rice Mill. This includes crop planning, crop monitoring, and crop harvesting. However, the SMS feature is not yet available at this stage.

2. METHODOLOGY

The Kanban is a popular framework for implementing Agile and DevOps software development (Figure 1). A Kanban board is used in order to visualize the current status of work items which allows team members to completely understand the state of work progress in relation to the designated timeline. Activities are represented by columns that form a workflow. These can be classified under "To-do", "Development", "Testing", "Deployed", and "Done".

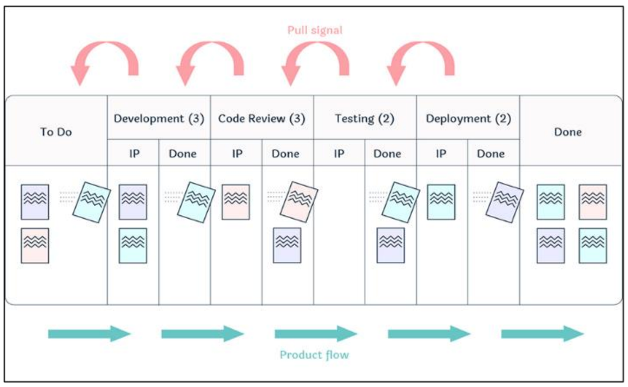

Fig. 1. Kanban Workflow Model

2.1 Kanban Team

The team consists of four members and a Service Delivery Manager. All members performed similar duties but of different backlogs. Roles were not required to be cross-functional, which was why the team decided to take the tasks according to the strengths of each team member. Workload and backlogs were self-assigned by each member. Furthermore, since the workflow in Kanban was intended to be used by all team members involved in the project, the team was allowed to work on anything that was on the list of To-dos.

2.2 Meetings

The team conducted retrospective meetings weekly, often conducted on each day of the week to brainstorm and discuss progress and roadblocks being undertaken. Additionally, 'weekly' stand-ups with their acting Service Delivery Manager were also scheduled on an as-needed basis. The team used Google Meets as the platform for their retrospective meetings in order to discuss the current progress and issues being faced by each member weekly. After each meeting, the team adjusted the Kanban board's project backlog accordingly.

2.3 Cycles

The group followed Kanban's continuous workflow process instead of Scrum's rigid sprint cycle in the ways they conducted their cycle.

2.4 Phases of Agile Methodology

The phases are as follows: Requirements Planning; User and Database design; Development; Testing; Deployment and Review. However, the last two phases are no longer covered in this study.

3. RESULTS AND DISCUSSION

Based on the data gathered and interviews conducted, there is a decrease in the yield due to inadequate risk mitigation of natural disasters, inefficient use of resources, and poor decision-making. The proposed system has three (3) modules, namely: (1) Crop Planning, (2) Crop Monitoring, and (3) Crop Diagnosis. A vital component of the system is the utilization of supporting features such as Geotagging, Weather Forecasting, and Remote Monitoring, which allows the automated capture and storage of environmental conditions of individual farmlands. Weather forecasting is used as an input source for the use of other functions within the system, specifically for the Crop Planning and Crop Monitoring modules of the system. Please refer to Figure 2 for the Conceptual Framework that includes the features and outputs generated by the system.

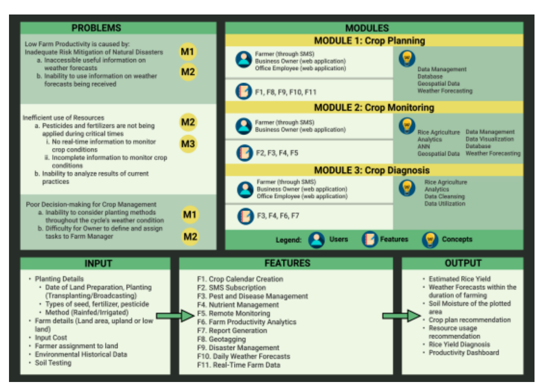

Fig. 2. Conceptual Framework

3.1 Crop Planning

The system provides real-time weather forecasts for the next 14 days (medium-range forecasts), including daily temperature, humidity, precipitation, and UV index information using AgroAPI. These data are automatically entered and updated accordingly and are stored in the database. The end user does not need to input anything else should they want access the weather information. This feature is the basis for weather alerts on impending natural disasters and recommendations on the recommended crop calendar dates. Refer to Figure 3 for the sample screenshot.

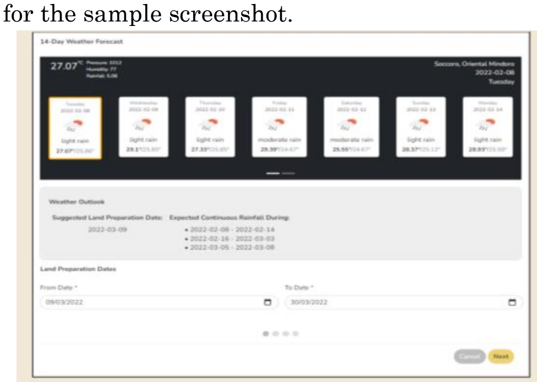

Fig. 3. Screenshot of 14-day Weather Forecast

3.2 Crop Monitoring

It provides the necessary information they need to make decisions on their operations. The information that will be generated are weather forecasting, humidity, precipitation, and geospatial data, which will be integrated with the other features of the system to provide a comprehensive and accurate overview of the current crop conditions of the plots. Short Messaging Services (SMS) will also be utilized to provide timely notifications and alerts of impending natural disasters, the presence of pests and diseases in nearby areas, and tasks ordered by the respective farm managers. Refer to Figures 4a and 4b for recommended solutions based on symptoms.

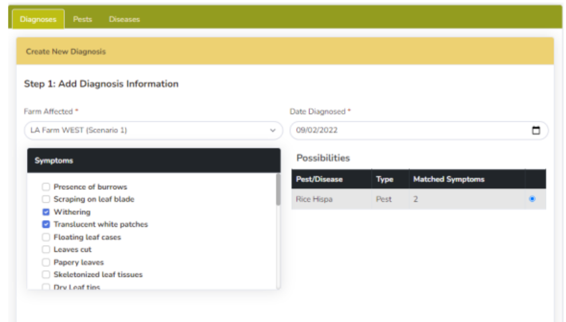

Fig. 4a Create Diagnosis (select symptoms)

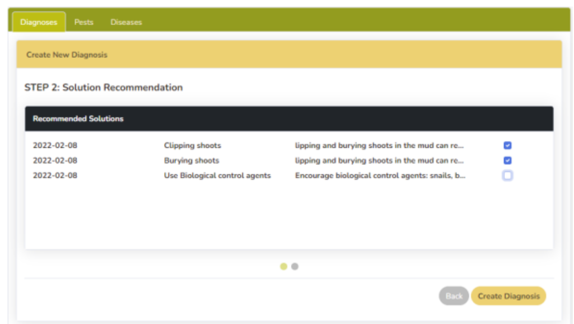

Fig. 4b Select Recommended Solution

3.3 Crop Diagnosis

It relies heavily on diagnosis reports on expected and actual farming results, pest and disease incidents, and input resources used during the crop cycle. This information will be the basis of the farm productivity analytics reports, containing the farm productivity and harvest reports. In the Detailed Harvest Report (Fig. 5), the scatter plot shows the relationship between the timing and amount of recommended nutrient applications vs. actual applications, wherein having two plot points in close proximity indicates that the farm followed the recommended nutrient application. It presents the data linearly by days in the x-axis and other areas of concern are the data plots concerning pests and diseases, implying its diagnosis according to its date of appearance, where the significance of the relationship between pest and disease occurrences with K nutrient application is revealed. In other words, a lack of K nutrient application leads to more pest and disease occurrences.

Fig. 5 Detailed Harvest Report

The group performed an operational acceptance test with the business owner and office employee to confirm the system's effectiveness in addressing the organization's requirements. The User Acceptance Test Form that was created used a Likert scale of 1-5 for measuring the responses (1 - Strongly Disagree to 5 - Strongly Agree). The questions are divided into three categories: Design, Functionality, and Usability, with each having its own subcategories to provide a more detailed breakdown.

Table 1. UAT Design, Functionality, and Usability Results

Category	Average Score
Design	**4.4**
Color	5.0
Typography	4.1
Layout	4.0
Functionality	**4.0**
Effectiveness	4.1
Function	3.8
Usability	**3.6**

Table 2. UAT Results for Separate Modules

Category	Average Score
Crop Planning	3.9
Crop Monitoring	3.6
Crop Diagnosis	3.2

The results show that the organization is in full support of the system since it addresses the problem areas. Not only did it gain positive UAT results for design, functionality, usability, and each module, but it was also deemed operationally feasible. They see this system as beneficial because it is not intrusive or too restrictive but seen as support that addresses the problem areas that contribute to their low farm productivity.

The Business Owner found the system comprehensive as it encapsulates the whole cycle of rice farming. He approved of the details and other information present in the system and acknowledged it to be of great value for the organization. In addition, the Business Owner suggested additional charts for the Reports Page to compare the early and late crop production for the same farms as well as the yearly crop production based on seed type. The said comparison is used by the organization to evaluate the performance of the farm on a year-round basis. He also noted that the existing charts in the system could be improved into digestible pieces of information that are easier for the eyes. For the Office Worker, she suggested emphasizing the resource material consumption especially for fertilizers and pesticides to closely monitor its usage. She would want to move some details in the Materials Management page to the dashboard instead. Furthermore, although out of scope, users recommended adding an accounting module that considers the revenue and expenses of the organization such as profit, materials, labor, and electricity which would make the farm productivity maximization more accurate.

4. CONCLUSIONS

The proposed solution will greatly benefit the farm owners since it will allow them to adapt precise agriculture using ICT and they do not need to frequently go to the site to check on the crops. It provides optimal decisions in rice production, which would both be adaptive and effective to the changing environmental conditions. Based on the post-mortem analyses on the harvested farms, farm owners can make the necessary adjustment or plan of actions for the next cycle to improve their farm productivity and harvest performance results. One feature that will be essential in the future is the soil data analysis for nutrient management. An expert on this could be consulted to help interpret the results of the analysis.

5. ACKNOWLEDGMENTS

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