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Smart Rice Agriculture Pre-Harvest Literature Review

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Abstract

Rice is one of the staple meals in most countries in the world. The rice demand continues to grow, and the rice production techniques and practices must continuously improve to properly address the future needs of the consumers. Through innovation and adaptation of the new technology in smart rice agriculture, a farmer's work in the rice field is made easy. Planting, monitoring, and disease detection are done with the aid of technology that saves up time, energy, and resources. As technology progresses, the avenue for precise and efficient smart rice agriculture continues to grow. This study focused on conducting a literature review on the articles related to smart rice agriculture during the pre-harvest phase from 2017 to 2021. Studies that addressed the problems and challenges in rice agriculture involve that utilized big data, machine learning, or the application of the internet of things to create sustainable and efficient solutions to improve the quality of rice farming through technology application.

Keywords: Smart rice agriculture; Internet of things; Rice farming; Rice agriculture; Rice pre-harvest

Introduction

Rice is consumed by more than half of the world's population; 480 million metric tons of milled rice are produced each year [1]. Rice is a member of the *Oryza* L. genus, including about 25 species in the tropics and subtropics, and it requires special attention to thrive. The producing the global rice demand, projected to reach 8.9 million by 2050, is still uncertain unless the problems and challenges in rice production are appropriately addressed [2]. Hence, researchers continuously conduct studies to develop techniques further to improve rice farming methods and eventually production.

As technology progresses, it paved the way for the utilization of modern methods, and devices in the agricultural sector. Smart farming is an innovative technology for managing and improving farming operations particularly in rice production as it is projected to be strongly influenced by the three areas of smart farming: Big data, machine learning, and the internet of things [3]. Big data is a massive collection of data that continues to grow dramatically over time. It is a data set that is so huge and complicated that no typical data management technologies can effectively store or process it. Big data is similar to regular data, but it is much larger. Machine learning on the other hand is a crucial part of the rapidly expanding discipline of data science. Algorithms are trained to generate classifications or predictions using statistical approaches, revealing crucial insights in data mining initiatives. The data collected from the sensors of the devices deployed in the rice fields will dramatically influence the machine learning algorithms to improve modeling processes and produce useful information that will utilize to enhance the quality of rice production. The Internet of Things (IoT) is a network of physical devices called "things" that are equipped with sensors, software, and other technologies in order to connect and exchange information between devices and systems over the internet. The tremendous improvement in IoT increased its usefulness in every aspect of life, including the area of agriculture, due to its ease of use, low cost, compatibility, and high quality of service [4]. Researchers have used IoT solutions to automate various farm functions, including plant monitoring, managing environmental factors, insect/pest monitoring, autonomous watering, food storage, supply, and many more. IoT technology allows remote access to the rice field without requiring the farmer to be present in the area. It reduces human effort, and helps save more time. It also reduced the production cost by continuous improvement of rice farming practices [5].

Literature Review

The purpose of this literature review is to look into how the different aspects of Smart Farming, such as big data, machine learning, and the internet of things, was used in rice farming pre-harvest processes. It specifically aims to answer the following research questions, using the guidelines of SLR [6]:

- What are the motivations of the studies in smart rice agriculture?
- What are rice farming areas covered by smart rice agriculture studies?
- What are the device components used in smart rice agriculture?

This SLR gives a systematic description for researchers in smart pre-harvest rice agriculture in terms of planting, growing, pest, and disease monitoring that helps to gain research implications, solutions, and future directions.

Using the SLR mechanism's article selection procedure the systematic review was successfully conducted [7-10].

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The review selection technique is depicted in Figure 1.

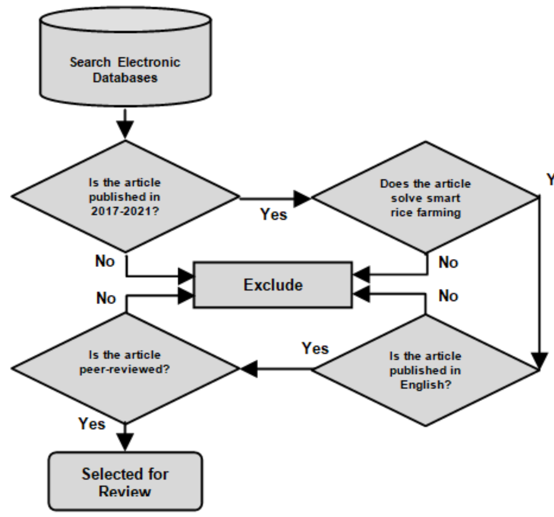

Figure 1: Selection method.

The databases IEEE Explorer, Elsevier, Springer, and Google Scholar were accessed to find the research articles using the following keywords:

("Smart Rice Agriculture" OR "Smart Rice Farming" OR "IoT in Rice Farming" OR "Internet of Things in Rice Farming" OR "Rice Farming Technology" OR "Automation in Rice Farming") AND ("Internet of Things" OR "IoT").

A total of 233 articles were found using the SLR method. Based on the following inclusion criteria, the final articles were selected:

- Application of big data, machine learning, or IoT techniques to solve rice farming issues during pre-harvest.
- Publication period from 2017 to 2021.
- Articles published in English, and
- Articles published in a peer-reviewed journal.

The research articles that did not pass the inclusion criteria are excluded from the final paper review.

After using multiple selection criteria, 14 articles as shown in Table 1 were chosen for review. The articles were examined, analyzed, and categorized into smart rice farming applications.

Motivations of using smart farming

The research motivations of the research articles reviewed in this study mainly focused on rice pre-harvest technology which only covers soil testing, planting, irrigation, pest control, and disease monitoring.

There are four main motivations identified in the papers reviewed in this study. Based on Figure 2, M1 is the first motivation that has one paper focused on improving soil testing in the rice field which is primarily caused by high laboratory soil testing rates that is not idea for small scale rice farmers. It would take time to wait for the soil testing result in the laboratory. Thus, a faster and cheaper way to address this matter would make things affordable and easier. The second motivation (M2) also has one paper that focused on improving the rice transplanting process of paddy through developing devices that provides efficacy and accuracy. M3 which is the third motivation got the highest number of relevant motivations for the conducted study in the area of smart rice farming. 8 studies are motivated to reduce human effort in monitoring the irrigation of the rice field. This will address the flood problem in excess irrigation and will accurately provide data on actual soil moisture of the area for the need plant water volume. The fourth and last motivation (M4) is focused on improving the disease and pest monitoring of the rice plant. Four papers conducted a study on how to determine and monitoring the disease and fest infestation in the rice fields. These had brought innovation on how to efficiently determine and monitory rice disease and pest infestation in cost efficient manner.

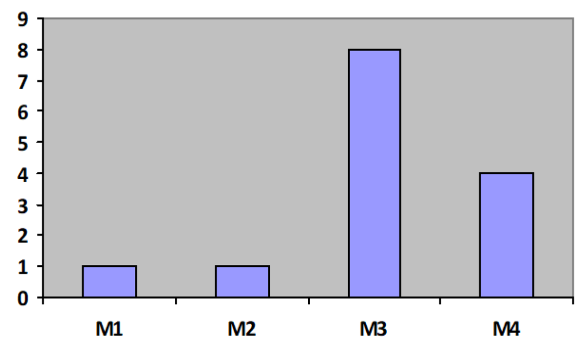

Figure 2: Motivations of the reviewed papers.

Discussion

Application of smart rice agriculture

Table 1 shows the important points from the articles reviewed in this study to answer the RQ2 with regards to the rice farming areas covered by smart rice agriculture. Rice pre-harvest happens during the soil preparation, seedling, planting, and growth monitoring. These are the essential stage in the rice production cycle to ensure high yield.

Smart farming aspect	Application area	Gateway	Sensors and actuators	User interface	Technique/algorithm
Big data, internet of things	Soil testing	Arduino Uno	MCP3204, DHT11, FC-28, PH value sensor, NPK sensor	Mobile and web application	Saves data to the cloud for testing
Internet of things	Planting	Microcontroller	NJK-5002C M12, DH48J-8, Phantom Miro M310	Desktop	Utilized hall effect in transplanting rice

Big data, internet of things	management	Arduino	Temperature sensor, pH value sensor, water flow sensor	Mobile and Web application	Automated flood control
Big data, internet of things	Soil and irrigation management	Arduino Nano and Raspberry Pi	Soil moisture sensor, air humidity sensor, light sensor, water level sensor	Web application	Uses four types of sensors
Big data, internet of things	Soil, irrigation, and light management	ATmega328p	Si7021, pH, sensor, DSB18B20, BH1750, HCSR04	Mobile and web application	Uses wireless network protocol
Big data, internet of things	Soil, irrigation, and fertilizer management	Arduino Uno Mini	Soil moisture sensor, temperature sensor, chlorophyll sensor	Web application	Determines plant nitrogen content
Big data, internet of things	Soil and irrigation management	ARM microcontroller LPC2148	HR 202, ORP12 Cadmium Sulphide photoconductive cell, PRD180	Mobile application	Sends SMS notification
Big data, internet of things	Soil and irrigation management	STM32F103VC	Liquid level sensor, soils moisture sensor, soil fertilizer detection sensor, ultrasonic sensor, SIM800A, SIM900a	Mobile and Web application	Saves data to the cloud through GPRS
Big data, machine learning, internet of things	Soil and irrigation management	Arduino Uno	DHT11, rain sensor, soil moisture sensor, GSM module	Mobileapplication	Uses Fuzy logic control to obtain high accuracy
Big data, internet of things	Soil and irrigation management	Arduino Uno	Node MCU 8266, soil moisture sensor, water flow sensor	Web application	Controls water flow
Big data, machine learning, internet of things	Disease detection	Raspberry Pi 3 Model B	DHT11, FC-28, LM393	Desktop	Image processing using artificial neural network technique
Big data, machine learning, internet of things	Disease detection	Arduino Uno R3 Module	L293D chip, TCRT5000, ultrasonic sensor, Wi-Fi module, SG90 9 g, multispectralcamera	Web application	Transfer of data as messages
Big data, machine learning	Pest and disease detection	-	-	Desktop	Image processing using Gaussian Naive Bayes
Machine learning, internet of things	Pest infection monitoring	Raspberry Pi 3	L293D	Desktop	Automatically sprays pesticides

Table 1: List of reviewed studies area of application and their device component.

Big data in rice farming: Almost all of the paper reviewed in this study collects data from the rice plant or the rice field and either sends it straight to the farmer or sends it through the cloud for storage and analysis. The data that are collected from soil sensors are useful in determining the nutrient content of the soil for the farmers to guided appropriately on what needs to be added on the soil preparation prior to planting [6]. Soil moister sensors gathers data that are highly useful in irrigation management of the rice field, the data collected will be used to control water flow and even prevent flooding in the rice field. Images from the rice plant in the field are also used as data to detect diseases and pest infestation.

Machine learning in rice farming: The data collected in the rice field are crucial in supplementing the algorithm used in some of the reviewed studies. A study that uses machine learning technology that process a variable through the possible truth values that is called fuzzy logic was utilized by a study to obtain high accuracy result in monitoring soil moister in providing good irrigation to the rice field. The data gathered are also used to prevent flooding in the rice field. The of artificial neural network and Gaussian Naïve Bayes techniques in image processing of the photos taken from the rice field are all beneficial in accurately detect disease and pest infestation on the rice plant. Machine learning is also used to automatically spray pesticides to the infected are of the rice plant.

IoT in rice farming: The use of the gateways and sensors in order to developed the internet of things devices that are capable of gather useful data plays a great role to the success of the studies conducted to enhance the current state of technology in smart rice pre-harvest. The two most common gateways used are the Arduino and Raspberry Pi. A device was developed to accurate help farmers in planting rice efficiently and cost-effectively through transplanter that has a hall sensor that analyzes the space between each rice plant [7]. The most commonly used sensor found in almost all of the reviewed papers is the soil moisture sensor, which is used to measure soil moisture and transmit the collected data for the farmers' utilization. The acidity level of the soil and water is also measured through the pH sensor [8,9]. The light intensity sensor that used to determine the amount of light that is reflected in an area, making it ideal for determining the amount of sunshine in rice field [10]. The water level for the irrigation is measured through an ultrasonic sensor [11]. All of these sensors are important for the development of the devices that improves the rice farming practices particularly in pre-harvest.

Device components used in smart rice agriculture

The device components used in the reviewed studies are shown in Table 1 to utilize the application of the internet of things in rice farming. In order to develop technology to boost rice production, it is critical to have a deeper understanding of the functions and applications of these device components. The following components are identified from the reviewed studies to answer the RQ3 of this study.

The gateway: In the world of the internet of things, a gateway is a device-to-device or device to cloud communication solution that enables IoT communication. In most cases, the gateway is a piece of hardware that houses software that performs key functions. The gateway, at its most basic level, makes it easier to connect diverse data sources and destinations. It is a microcontroller that functions as a connector between sensors, cameras, and the cloud. It collects all sensory information, processes it, and then sends it to the cloud. The most common gateways are Arduino and raspberry pi due to their popularity in terms of robust application and cost-efficiency.

Arduino: Arduino began in 2005 as a project for students at Italy's Interaction Design Institute, Ivrea, Italy. It is a single-board microcontroller that is open-source. An Atmel 8-bit AVR is used on an Arduino board. A microcontroller with additional components that make it easier to integrate with other circuits and programs. Also, Arduino's standard connectors are its key feature. The CPU board can be connected to a variety of devices. Shields are a type of interchangeable add-on module and sensors that are used in monitoring rice field environments, such as testing soil moisture, humidity, and temperature. Arduino boards come in different types, such as the Arduino Uno, Arduino Due, Arduino Leonardo, Lilypad Arduino, Arduino Micro, Arduino Esplora, Arduino Yun, Arduino Robot, Arduino Pro Mini, Arduino Blue Tooth, and Arduino Ethernet. The Arduino boards are different in terms of the processor and features built into each board. The most popular Arduino board is the Arduino Uno for its simplicity and convenience that easy to use for beginners in electronic projects.

Raspberry Pi: It is a low-cost, credit-card-sized single-board computer designed in 2012 by the Raspberry Pi Foundation in the United Kingdom to promote the teaching of basic computer science. It has been considered as a computer built to transform the world, because it can perform most of the tasks that a desktop computer can, such as web browsing, video streaming, word processing, playing games, programming.

It can also be used to monitor rice farming parameters to improve rice yield. The Raspberry Pi A^+, Raspberry Pi 2 Model B, Raspberry Pi Model B^+, Raspberry Pi 3, and Raspberry Pi 3 Model B^+ are some of the models available, each with various CPUs and capabilities. The most popular raspberry pi that is available in the market right now is the Raspberry Pi 4 B. It is low-cost and powerful enough for any type of project. It is even for some light internet surfing.

IoT Sensors: Table 2 shows the following sensors that are utilized by the papers reviewed in this study.

Sensors	Model/type used in the studies	Function
Soil moisture	FC-28,	Used to monitor or estimate the amount of water in the soil.
Temperature and humidity	DSB18B20, DHT11, Si7021, HR 202	Used to monitor the ambient air.
pH Value	-	Used to measure the acidity and alkalinity level of the water.
NPK	-	Used to detect soil fertility. Nitrogen, phosphorous, and potassium are all essential components of soil fertilizer.
Water flow	-	Used to measure the rate of flow of water.
Light	BH1750	Used to determine the amount of light that is reflected.
Ultrasonic	HCSR04, TCRT5000	Used to determine the distance between two objects.
Chlorophyll	-	Used to measure phytoplankton densities.
Hall effect	NJK-5002C M12	Use to measure the changing voltage when the device is placed in a magnetic field.

Table 2: List of sensors used in the reviewed studies.

The sensors used in the development of the devices in the paper reviewed are essential to its contribution in alleviating the current state of technology in smart rice pre-harvest. Soil moisture such as the FC-28 can be fixed or mobile, like handheld probes. Stationary sensors are placed at predefined locations and depths in the field, whereas portable soil moisture probes can test soil moisture at many places. The DHT11, a basic digital sensor for temperature and humidity that is cost-efficient, and the most popular digital temperature and humidity sensor. When compared to the Si7021 temperature sensor, Si7021 employed a greater rate of accuracy; it is an industrial-grade temperature and humidity sensor. The HR 202 humidity sensor is also used to amount of water vapor in the rice field.

In terms measuring the level of acidity and alkalinity level of the water irrigation in the rice field. The pH value sensor plays a crucial role. Though in the reviewed studies, the specific model of the pH value sensor was not specified. The understanding of soil nutrient concentrations can assist farmers in determining if soils utilized to support plant production are nutritionally deficient or abundant. The NPK sensors are used to detect soil fertility. Nitrogen, phosphorous, and potassium are all essential components of soil fertilizer. The specific model of the NPK sensor was not determined in the study. The rate of water flow was measured as the water passes through the rotor, the flow rate increases depending on the volume of water that passes through the rotor. The specific model of the water flow sensor was also not identified in the study that used it. The HCSR04 Ultrasonic Sensor water level sensor measures the water irrigation intake regardless of how bright or foggy is the rice field. It ensures adequate water level in the field. The TCRT5000 which is an infrared sensor unit was utilized to calculated the distance of the object in front of it. The chlorophyll sensor is used for water quality monitoring. The information could help predict harmful algae blooms and, in turn, determine fertilizer loading in environmental applications. Though, the specific model of the chlorophyll sensor was not determined in the study that used it. The NJK-5002C M12 was used as a hall effect sensor to accurately transplant rice paddy into the rice field [12].

Conclusion

The application of technology in smart rice agriculture is vital to the growth of rice production, particularly in the rice-producing countries of the world. Big data analytics plays a great role in data gathering and processing to create useful information that will continuously improve the practices in smart rice agriculture. The approaches and techniques in the field of image processing to detect pest infestation and rice plant diseases will significantly improve the yield of rice farmers. This involved the machine learning aspect of the systems developed to address smart rice farming challenges will help create smarter systems to address the needs of rice farming in terms of producing useful information that will better help rice farmers in decision making towards rice production. The Internet of Things developed systems are all beneficial in the areas of rice farming, particularly in planting, irrigation, pest control, and disease detection [8]. As the technology continues to progress, the viability of the microcontrollers and actuators to produce more efficient and useful technology to better help the smart rice agriculture industry in ensuring that there will always be rice on our tables. In this review, the motivations areas of smart rice agriculture application in pre-harvest technology were determined, and the systems, devices, and sensors were illustrated.

The future is bright for smart rice agriculture. However, there is still a lack of study in the areas of planting and harvest though large agricultural manufacturing companies all over the world continuously develop industrial machinery to address this area of application in smart rice agriculture. Further application of artificial intelligence will also improve the autonomy of the systems developed and produced accurate results in terms of the testing being conducted onsite. The developed systems and devices are mostly prototype and was not applied in the actual mass rice production. The development of more advanced gateways and sensors will improve the current systems. This will also open up the avenue to a more cost-efficient development. Some studies did not clearly indicate the model of the sensors they have used. Further study that focused on the area of big data, machine learning, and utilization of internet of things in the post-harvest rice are needed to better determine the impact of smart rice agriculture in rice production.

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