A Research Review of Precision Farming Techniques and Technology

Bryan Mungai Njoroge[1]; Thang Ka Fei[2]; Vinesh Thiruchelvam[3]
[1,2,3]School of Engineering, Asia Pacific University of Technology & Innovation,
57000 Kuala Lumpur, Malaysia
[1]brayomungai2000@gmail.com; [2]dr.ka.fei@apu.edu.my; [3]dr.vinesh@apu.edu.my

Abstract- **Recent technological developments and advancements in soft computing (decision support systems) and information technology have paved way to the development of precision-based agriculture. These new trends have enabled the exploitation of modern techniques and tools such as wireless sensor technology, soft computing techniques and IOT to improve the economic and environmental sustainability of agricultural production. The new trend of precision farming /agriculture distinguishes and discerns itself from the traditional techniques of farming through efficient, planned, systematic and justified use and application of resources for improved and increased yield production. In order to achieve this, precision farming exploits soft computing tools such as Support Vector Machines (SVM), Fuzzy Logic (FL), Artificial Neural Networks (ANN), Decision Trees (DT), geographic information systems such as weather patterns and remote sensing technologies such as Wireless Sensor Networks (WSN), to monitor and predict real time and future requirements of farm produce for improved food security. This research paper reviews the application of various techniques and technologies employed in precision farming.**

Index Terms - Precision agriculture, yield management and monitoring, Sensing technologies, soft computing technologies.

1. Introduction

According to data collected and analyzed by researchers from the UN food and Agricultural Organization, the world population is estimated to reach an estimated 9.5 billion people by 2050 thereby resulting into a global food crisis (UNEP, 2017). Farming of more crops and rearing/production of more animal produce is considered as an unsustainable solution mainly due to the shortage of land created by the increased global population and the shortage of resources required for plant/animal sustenance. What is required is improvement in the current farming techniques for greater and sustainable efficiency. One recently adopted sustainable approach is precision farming which combines a number of new technologies to collect and transmit a wide range of field data for effective analysis and intuitive decision making (Ambarish and Saroj, 2016) is shown in Figure 1.

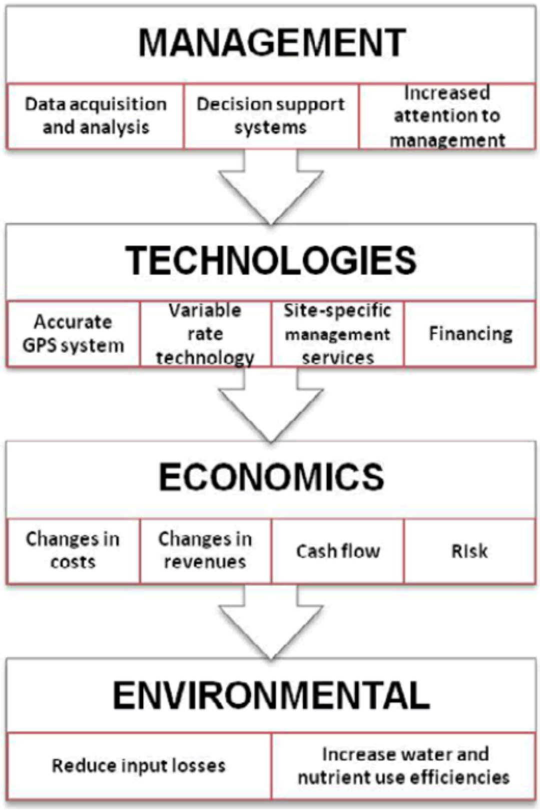

Figure 1: Considerations for Precision Agriculture (Ambarish and Saroj, 2016)

The main aim of precision farming is to improve and increase production efficiency while minimizing the negative effects and environment degradation associated with under and over utilllisation of resources such as pesticides, water, fertilizer, insecticides and seeds. Some of the reliable tools and technology used in the management and collection of data for analysis and decision making include WSN (Wireless Sensor Network), IOT (Internet of Things), intelligent algorithms, weather modelling, mobile devices (GPS/GNSS/GPRS) and robotic systems. According to Jones and Barnes (2014), the four major phases involved in precision farming include data collection, analysis of collected data, decision management (resource allocation and yield prediction) and finally application. A comparative study will be conducted in this research paper based on the techniques applied in precision farming in terms of applications, decision support systems as well as field data collection and analysis techniques.

2. Decision-Making Platforms for Precision Farming

A variety of new soft computing technologies has been proposed and adopted for monitoring and making precise decisions based on field data collected from sensors. An AI based intelligent control system has been proposed by Pahuja et al. (2013) for development and synthesis of a smart climate controller for precision farming in greenhouses. The system proposed employs Artificial Neural Networks (ANN) for control of humidity and temperature in artificially weather conditioned green houses. The intelligent controller proposed by Pahuja et al. (2013) presents a unique approach of applying artificial intelligence in regards to precision based farming within a greenhouse.

Lamorski et al. (2013) performed a comparative study to estimate soil water requirements from quantified soil properties using Support Vector Machined (SVM) and Artificial Neural Networks (ANN) for precision farming. The outcome of the research showed that the three variable SVM's were more effective with the same level of accuracy as the eleven variable ANN's. However, the correlation between the measured and the predicted soil water content was relatively lower using SVM due to the presence of high soil matric potentials resulting mainly from relative errors.

In another study related to precision-based farming Karim et al. (2014) employed remote hyperspectral image analysis using SVM and ANN as instruments for detecting and classifying weeds on a corn field with the aim of intelligently controlling the amount of nitrogen application for weed management. In their research, the SVM technique achieved low misclassification rates and high generalization ability in comparison to the ANN. In this research a conclusion is arrived that SVM is best suited for the effective detection and control of weeds.

A Precision crop management system using a fuzzy controller was proposed by Jones and Barnes, (2014). In their work, two expert models were applied by employing Fuzzy Logic (FL) rule base system. In one expert model physical and chemical traits of the soil were measured and integrated with local weather data as crisp inputs whereas in the other model, soil parameters in terms of water use, runoff and drainage were approximated through prediction analysis and their effect on the crop yield as shown in Figure 2.

A comparison was then performed between the model estimated and measured yields for the fields tested. The results obtained from this research verify that the predicted yields obtained using the Fuzzy based decision support system was more accurate in comparison with the measured yields (Jones and Barnes, 2014).

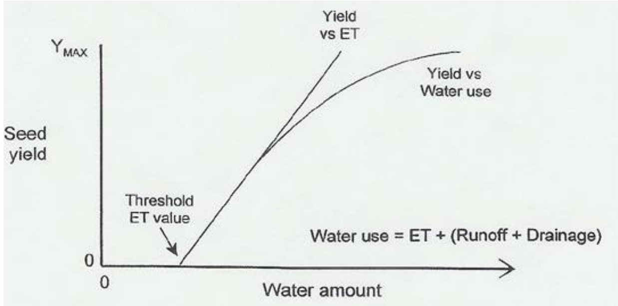

Figure 2: Relationship between Water and seed yield (Jones and Barnes, 2014)

The implementation of agricultural data with visual data mining technology are depicted by Yash et al. (2015) whereby high dimensional agricultural field data mined is reduced to smaller dimensions with the purpose of deriving important knowledge related to yields in precision farming such as fertilizer and water application. Self-organizing maps and Sammon's mapping technique is used to disintegrate the large data base into smaller interpreted data for quick and intuitive decision making. The conclusion derived from this research paper is that Sammon's mapping technique is only suitable for small data sets whereas Self organizing maps are conducive for large data.

A Guelph Intelligent Greenhouse Automation System (GIGAS) for greenhouse-based precision agriculture has been proposed by Halimi and Moussa (2015). The Guelph Intelligent Greenhouse Automation System presented in this research is an intuitive robotics system with outstanding functional capacity for greenhouse applications. The system proposed uses a machine vision system consisting of a number of cameras which are used to take a variety of real time images of plants. A plant data base is created to track the development of all the plants within the greenhouse to enable the intelligent system to make intuitive decisions and resource planning for the plants (Halimi and Moussa, 2015). The intuitive decisions made by the intelligent system are sent to the robot for execution purposes. Results from this research indicate that 92.3% production efficiency is achieved using GIGAS whereby a 63.2% increase in yields was achieved.

Thalheimer and Rakesh (2015) present a system for continuous analysis and measurement of plant growth using a microcontroller and an optoelectronic reflex sensor. The principle of operation of the proposed system is reliant on the detection of contrasting black and white bars visible of a roll of adjustable tape that allows for continuous measurements to be made. Plant growth is measured in terms of the changes observed in the fruit of the plant and overall perimeter of the stem thus providing a sustainable data base for monitoring plant growth and allowing the farmer to intuitively allocate resources to the plant. It also enables timely harvesting of the plant as soon as maturity is reached.

Lee et al. (2016) and Twarakavi et al. (2015) make a comparative research study of classification algorithms and their application in yield prediction in precision farming systems. The algorithms implemented in this research have been assessed for a period of several years for yield prediction in soya beans. The algorithms assessed and evaluated in this research for yield prediction include Support Vector Machines (SVM), Neural Network (NN) and Bagging as shown in Table 1.

The conclusion drawn during evaluation of the systems is that Bagging is considered as the most suitable and accurate algorithm in relation to yield prediction for precision farming since the error deviation realized is low with a mean absolute error of 18985.7864 as shown in Figure 3 (Lee et al. 2016). Yield prediction is used in this research to enable the farmer to effectively plan for harvesting, resource allocation for present and future planting seasons.

In Ambarish and Saroj (2016) prediction of hourly soil moisture requirement is presented using two algorithms based on neural networks i.e. Scaled Conjugate Gradient (SCG) and Quasi newton BFGS for WSN based precision farming. The performance of the two algorithms proposed was tested and studied on a 50m by 100m Bermuda grass field in terms of their ability to predict soil moisture content for every hour by putting into consideration unique environment, soil parameters and the actual soil moisture content at the given time. According to Ambarish and Saroj (2016), the Scaled Conjugate Gradient (SCG) neural network pattern produced better results (Figure 4) in comparison to the Quasi newton BFGS based on the Mean Square Error and Root Mean Square Error as shown in Table 2.

Table 1: Potatoes yield prediction based for two fields

		Field 67-S		Field 44-S	
Algorithms used	Yield prediction results	Fresh weight (Ton)	Dry matter (%)	Fresh weight (Ton)	Dry matter (%)
Support Vector Machines (SVM)	Predicted yield	1040	20.8	1123	20.4
	Actual Yield	957.26	20.8 – 21.0	1235.69	20.4
	Prediction error %	7.9 %		9.1 %	
Bagging	Predicted yield	995.00	20.8	1133.67	25.0
	Actual Yield	957.26	20.8 – 21.0	1225.48	25.0
	Prediction error %	3.8		7.5	
Neural Network (NN)	Predicted yield	1110.3	20.8	1210.3	19.8
	Actual Yield	1178.56	20.8 – 21.0	1324.56	19.8
	Prediction error %	5.8%		8.63%	

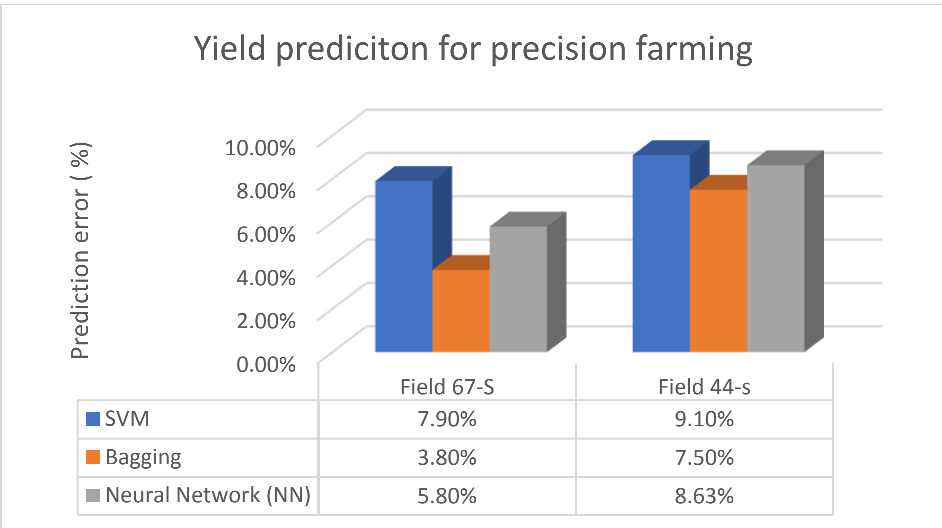

Figure 3: Yield prediction for potatoes (Lee et al. 2016)

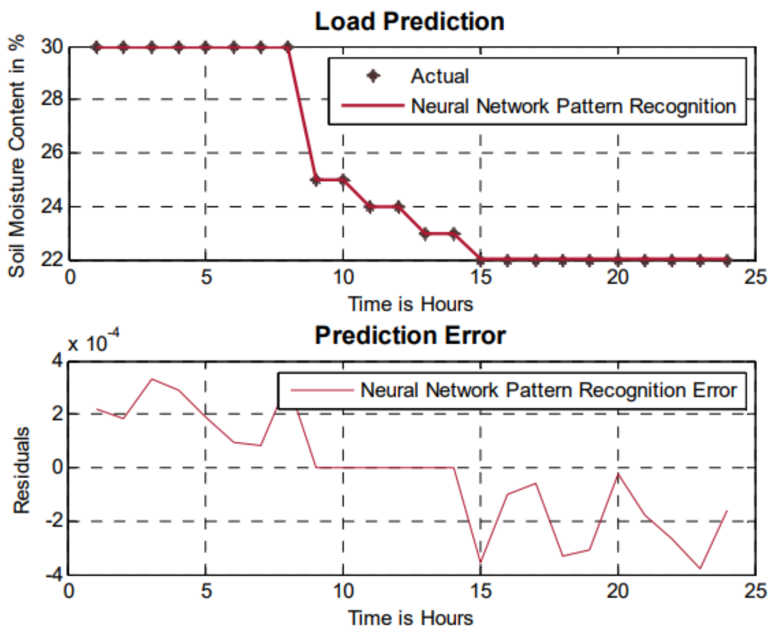

Figure 4: SCG Prediction error (Ambarish and Saroj, 2016)

Table 2: Error evaluation for the Neural based Algorithms (Ambarish and Saroj 2016)

Sl. No.	Algorithm type	MSE	RMSE	R-squared
1	BFGS Quasi-Newton	0.79167	1.207614729	0.997741935
2	Scaled Conjugate Gradient	6.2944e-08	0.000194606	1

3. Weed/Pest Eradication

Yang et al. (2014) looked at a weed detection and eradication system (Figure 5) based on image processing whereby a Fuzzy logic based decision support system was used to establish and deduce where and what quantity of pesticide to be applied on the plant field. The fuzzy logic controller was used to mainly to relay spray commands to the farmers based on the threshold of weeds detected in a given part of the farm. The findings from this research indicate that a fuzzy logic system has the ability to facilitate a high degree of precision based on the crisp data retrieved from the image sensors and FL rules.

A machine vision system for field weed detection based on natural lighting was proposed by Tang et al. (2014). A fuzzy cognitive map was used to develop the image based real time processing algorithm using image segmentation techniques and Hue- saturation colour space conversion was used for isolate the weeds from the crops from the overlapping background consisting of rock and soil residue. The results obtained from this precision-based system were mainly used for selective mapping and herbicide application for maximum weed eradication.

A crop pest management system based on colour textural analysis was adopted by Pydipati et al. (2015) and Tan to deduce if classification algorithms could be employed in the identification of disease infested citrus leaves. ANN classification algorithm was investigated in this research based on the Radial Basis Function (RBF) networks consisting of Fuzzy outputs used in the indication of strength.

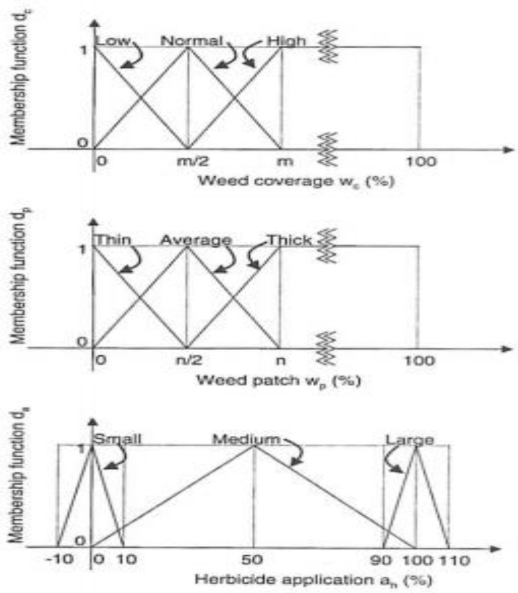

Figure 5: Fuzzy based weed detection and eradication model (Yang et al. 2014)

An adaptive UAV for crop pest management in dynamic terrain environments is proposed by Facial et al. (2016). The system proposed optimizes the current course correction approaches of UAV's employed for precision-based pest eradication by employing an evolved genetic algorithm to map the most suitable course correction based on dynamic weather and terrain conditions. The system proposed in this research provides a platform for UAV used for pest eradication to intelligently adapt their navigation behaviour based on cognitive vision and real time weather data retrieved from sensors.

Boissard et al. (2016) proposed a cognitive vision-based approach for prior pest detection and eradiation in green houses. The goal of the cognitive vision system deployed by the researchers is the early detection of peers using image processing and a machine-based learning algorithm. The system proposed relies on the early detection of the pest (whitefly) during its life cycle before and after maturity whereby features are extracted by employing gray type co-occurrence matrixes, histogram equalization, binary operation and neighbourhood connected properties of the pest images. Classification of the images retrieved from the vision system is done with the aid of Support Vector Machine (SVM). A summary of the findings observed from the review conducted based on decision making and analysis platforms is as illustrated in Table 3.

Table 3: Review summary of intelligent algorithms used in Precision farming

No.	Algorithm	Findings
1	Support Vector Machine (SVM)	• Low generalization error • Easy to interpret multiple sensor data • Sensitive to tuning parameters • Testing data should be near training crop data
2	Naives Bayes	• Suitable for small scale precision farming since it requires relatively small amount of training data set. • It can deal with some noisy and missing sensor data • Suitable for obtaining the probability of prediction of farm events • Prune to errors when increasing the number of sensor data training sets
3	Artificial Neural Networks (ANN)	• Suitable for weather prediction patterns • Some tolerance to correlated sensor data • Difficulty in dealing with large sensor data from a wide range of different crops i.e. fails to classify scattered sensor data • Costly
4	Fuzzy Logic controller	• Easy application and modelling of sensor data • Customizable • Cheaper • Requires manual tuning of membership functions for plant data depending on growth stage

4. Smart Sensors Application for Precision-Based Farming

Diaz et al. (2012) proposed a smart irrigation management system that relies on data collected and recorded from a humidity sensor using an intelligent low power wireless trans-receiver. A computer is used for monitoring the irrigation management data retrieved from the sensor and trans-receiver network. The retrieved processed data is then used by the researchers to derive soil moisture requirements for the plants as well as to predict/modify the irrigation timetable for increased yields. Kim et al. (2013) Proposes the use of a Wireless Sensor Node (WSN) consisting of a wireless ZigBee microcontroller (802.15) and a JN5121 module for wireless Sensor data retrieval and transmission for precision farming systems as shown in Figure 6.

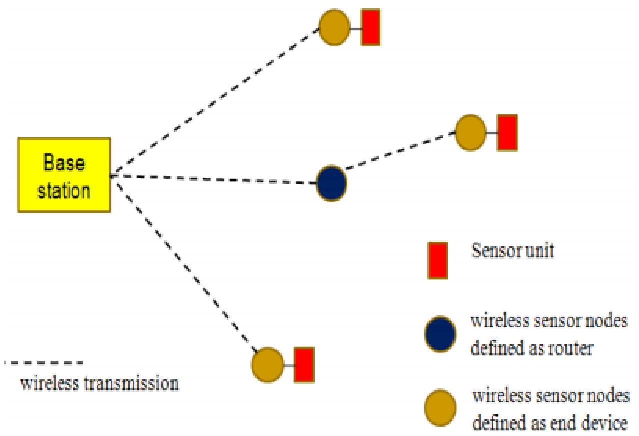

Figure 6: ZigBee and Wireless Sensor Network (Kim et al., 2013)

Data aggregating form the sink node was achieved using ARM9 Group of 32 Bit processor cores. Long distance sensor data transmission was achieved using a GPRS gateway and a mobile unit. The proposed design of a wireless node system in Tuna and Gungor (2015) and Tan and Panda, (2010) utilizes a ZigBee/RF module as the sole unit of achieving wireless communication of the sensor data, however unlike Kim et al. (2013) the researchers use a more advance module MSP430 as the core microcontroller unit. In addition, the system proposed consists of a web enabled user interface consisting of data mined from various agricultural expert systems. Real time data from the sensors is transferred to the sink node whereby sensitive data mined from the plants is transmitted and hosted to the web application for reference purposes by the farmer.

The research paper by Navaro et al. (2015) has proposed and performed an analysis of the utilllisation of a chip Based programmable system as part of Wireless sensor Network consisting of a ZigBee ZMN2405HP module for monitoring and controlling a series of parameters in a greenhouse for precision farming.

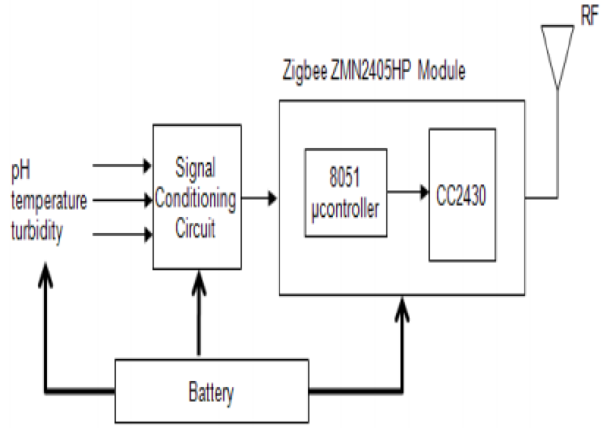

Figure 7: Proposed monitoring system (Navaro et al., 2015)

A low powered RF CC2430 PSOC kit consisting of a programmable IDLE software for sensing and data collection is used by the researchers as shown in Figure 7. The system proposed for precision sensing is used for collection and analysis of data collected from temperature, light and proximity sensors within the green house.

The system architecture proposed in Ratasuk et al. (2016), Cancela et al. (2015), Rani and Kamalesh (2014) is developed to monitor humidity and soil moisture parameters for precision agriculture. A variety of tests are conducted to verify the accuracy of the humidity and temperature monitoring systems in closed and open green houses. In their findings, the researcher's observed that the position estimation of the sensor nodes in the Wireless Sensor Network (WSN) included some errors whereby the average localization error decreased with coefficient related to signal propagation. In addition, the researchers concluded that the robustness of the system is adversely affected by bad environment.

A Precision Agriculture Sensing System (PASS) based on a network of wireless multimedia sensors is proposed by Irmak et al. (2015) in order to make certain that the needs of an adaptive modern precision agricultural system are met. The system proposed is designed to minimize the need of human supervision and interaction on a large farm. Bulky transmission of data on the farm is achieved with the aid of a bitmap index transmission mechanism and dedicated mono-chip sensors for the wireless multimedia sensor network.

In Ambarish and Saroj (2016) a WSN architecture consisting of nine wireless analog sensor nodes is proposed for monitoring Bermuda grass (Cynodon dactylon) as shown in Figure 8.

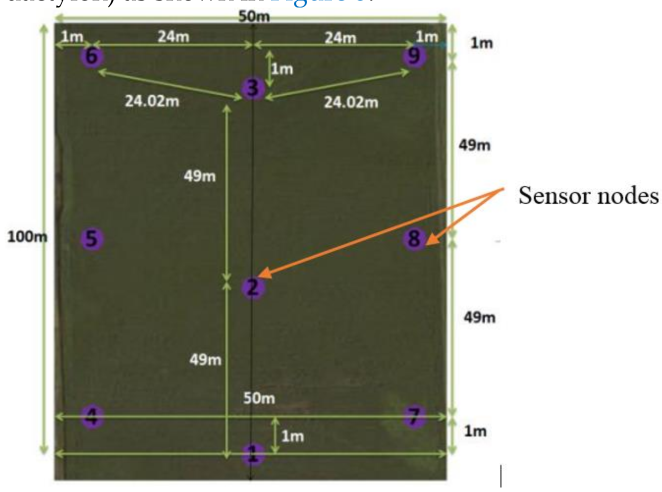

Figure 8: Nine WSN node Deployment (Ambarish and Saroj, 2016)

Each of the sensor nodes deployed consisted of a number of different types of sensors for monitoring and collecting data in terms of soil temperature, soil moisture, humidity and CO_2 sensors as shown in Figure 9.

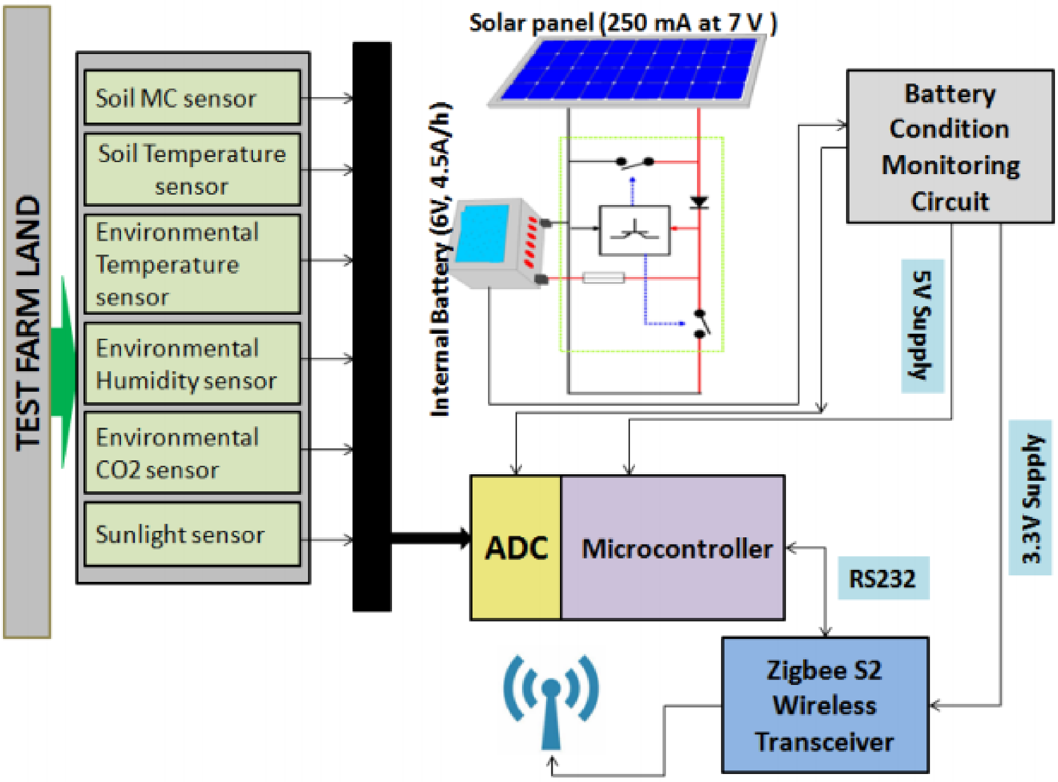

Figure 9: Wireless Sensor Node architecture (Ambarish and Saroj, 2016)

Interfacing of the sensors in Ambarish and Saroj (2016) was conducted with the aid of an ADC (Analog to Digital Converter) whereby energy conservation of the WSN network was achieved using a sleep mode function between any two successive data acquisition protocols. Wireless communication in this research was achieved with the aid of a ZigBee S2 integration with a Raspberry Pi whereby data is sent to a MySQL data base for real time monitoring.

Sai et al. (2016) and Srbinovska (2015) propose a network-based routing algorithm to lower the consumption of energy by data transmitting nodes for precision-based agriculture. In this research, the adoption of Wireless Sensor Networks in precision agriculture is also explored in regards to the "acoustic emission principle" for crop water requirements. The researchers propose a new technique for long distance transmission of complex sensor data using a routing protocol known as PECRP (Power efficient Clustering Routing Protocol) that is developed in Matlab 7.0.

The categorization of existing remote monitoring platforms and control systems is as shown in Table 4. The research papers analysed so far in this comparative literature review demonstrate the constructive and effectual utilisation of Wireless Sensor Networks in precision-based agriculture. A bulk of the research papers have proposed a number of schemes to improve the efficiency of the WSN, however the schemes proposed have not been deployed in real time but rather in simulation software such as Matlab, whereas those which have been successfully deployed in field, are only suitable for some crops. As identified by some researchers, various crops have varying requirements which are limited to that particular species/type. Therefore, it is necessary to undertake the design, analysis and implementation of a system that takes into account the specific requirements of a particular crop. The systems studied in this section of the literature review can be classified as shown in Table 4.

Table 4: Classification of existing control and monitoring systems used for precision farming

References	Sensors interfaced	Technology	Monitoring system	Module interfaced
(Kim et al. 2014)	Temperature and soil moisture	ZigBee, GPRS	Mobile phone	JN5121, ARM9
(Tuna and Gungor 2016) (Tan and Panda 2010)	Humidity, illumination, Temperature	ZigBee, internet	Laptop	CC2420, MSP430

(Diaz et al. 2011), (Irmak et al. 2006)	Light, moisture and temperature	RF, internet	Laptop	C43271
Navaro et al. (2015)	Temperature, humidity, PH	Sensor node(mono-chip sensors)	-	RF CC3271 PSOC kit
(Sai et al. 2016), (Srbinovska 2015)	Temperature, humidity	ZigBee	PC, Matlab 7.0	PECRP
(Sabri et al. 2012)	Temperature, humidity	ZigBee, SunplusSPCE061A	TFT-LCD	Chip (SoC)
Irmak et al. (2006)	Temperature, soil moisture, Humidity, CO2, illumination	ZigBee, Internet	PC	ZigBee module 3160
(Ratasuk et al. 2016), (Cancela et al. 2015), (Rani and Kamalesh, 2014)	Temperature, soil temperature and moisture, Humidity, Anemometer, illumination, rain gauge	ZigBee, Internet	Laptop, PDA	MSENS SoC,

5. Conclusion

In precision farming, to obtain high-quality products, the environmental parameters should be effectively monitored and controlled to provide optimal values. A review of precision farming techniques based on remote monitoring and control approaches have been presented in this research. A detailed comparison of various decision-making platforms employed for precision agriculture such as ANN, Bayes, SVM, Fuzzy Logic, and different wireless technologies and protocols used for monitoring sensor data such as ZigBee, internet, GSM and RFID have also been looked at. In terms of water and soil requirements for crop administration, a decision support frame work consisting of sensor derived data and fused or standalone soft computing techniques is a necessary requirement for long term sustainable yield production. Areas of application of soft computing include efficient irrigation, nutrient and fertilizer planning and management for optimization, early identification and eradication of crop weeds, diseases and pests and analysis of crop yield prediction. The research review conducted illustrated that effective implementation of WSN in precision farming is warranted since its success is reliant on the acquisition and processing of real time crop data. Some of the challenges incurred in precision farming can be tamed with the implementation of WSN with the aid of a discrete, intelligent, intuitive decision making and control protocol for effective yield production. In addition, the application of WSN in precision-based greenhouses is found to be beneficial since they are scalable, efficient, cost effective and easy implementation.

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