Fuzzy and Ontology Based Crop Prediction Using Wireless Sensor Networks & Internet of Things

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Abstract— **The drastic changes in the crop field creates the need for precision agriculture. Machine learning and Internet of Things (IoT) play a vital role in predicting crops based on the changes in the field. The main objective of this research work is to increase the productivity of crop and to provide proper guidance to the farmers to take profitable decisions at right time, throughout the entire farming cycle. The goal of this paper is to investigate the crop yield prediction using fuzzy rules and ontology indexing algorithms. Wireless Sensor Network (WSN) uses Micro Electro Magnetic System to measure temperature, humidity and moisture in the crop field. The obtained values from various sensors are collected and stored remotely by IoT. Climate is predicted by analyzing the sensed data of temperature and humidity at different locations using fuzzy rules. Using the predicted climate and pH value of the soil, the list of crops to be grown is predicted using fuzzy equation. The effective list of crops to be grown is generated by comparing the predicted crop list with crop knowledgebase using ontological indexing. Then, the effective list of crops to be grown is sent to the land owner's mobile through SMS using radiofrequency which consumes less power. The experimental results show that Fuzzy rules and ontology-based information retrieval efficiently predict the crop yield production. This research creates a prediction model which may be used to predict crops to be grown based on changing climate.**

Keywords— Crop Prediction; WSN; IoT; Fuzzy Rule-base; Ontology

I. INTRODUCTION

Now a days, IoT plays major role in future generation. Using IoT, the world around is getting automated by replacing manual procedures, since it is energy efficient and involves minimal man power. The Indian government has taken initiative in developing a secure and a smart system based on country's need using IoT. Smart city is major aspect focused by government such as smart parking, women safety, waste management, water management, Agriculture.

IOT have huge impact on smart farming since agricultural lands are destroyed due to lack of workers in the field. In Smart farming, the information required by the farmers are scattered in various places which includes real time information. This project proposes automated prediction of crop with the advantages of having ICT in Indian agricultural sector. It shows path for rural farmers to replace some of the conventional techniques.

Agricultural system is also automated regularly to monitor the watering [1]. IoT sensors have capability to provide information about crop yields, rainfall to the farmers etc. In future, IoT changes the way the food grow. This research paper overcomes the limitations of traditional agricultural procedures by utilizing water resource efficiently and also by reducing the labour cost. The paper is arranged as follows: Section 2 deals with the state of the art of IoT in agriculture. Section 3 describes the framework and the methodology of the proposed work. Section 4 discusses the results and Section 5 concludes the paper.

II. BACKGROUND

This section lists the literature in the field of IoT in agriculture. IoT node combines three fundamental components such as intelligence, sensing, and wireless communications. Some of the real time applications of IoT are precision agriculture, smart home, waste management, healthcare and transportation. Wireless Sensor Network consists of various sensor nodes deployed in huge numbers at different locations to monitor the environmental factors. The data sensed by the sensor are analyzed and processed to compare with the knowledge base. The crop prediction and animal prediction increase the efficiency of crop production [2].

The data in knowledge base are collected from various heterogeneous resources over several years. The heterogeneous resources consist of structured and unstructured information from agricultural researchers, Email, Web Crawling, farmers Profile, which leads to Big Data [3]. Big data analyzes and examines the both the structured and unstructured large data sets of agriculture field. Semantic extraction from big data using ontology is mainly to reduce the searching complexity, increase the accuracy, which in turn increase the performance of the system. The crop has been classified based on climate, soil type and Life span of crop. Based on Ontology Classification of crop using knowledgebase, the type of crop yielding best can be identified [4]. An advisory system is proposed [5] for cotton crop using cotton ontology, web services and Mobile Application Development.

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A monitoring system was proposed [6-8] to make the farmers to be more profitable and sustainable, since it provides better water management. During rainfall Condition, the land owners need not irrigate the land because humidity of the soil gets changed. Water can be saved which in turn consumes power. Hemlata Channe et al proposed a Multidisciplinary Model [9] for Smart Agriculture using Internet of Things (IoT), which increased the agricultural production and controls the cost of Agro-products. An ontology based information retrieval model was proposed [10] to improve the accuracy and reliability of the Agricultural information retrieval from knowledgebase. Agricultural ontology technique was used [11] to classify the efficient and significant attributes in crop prediction to enable the precision agriculture.

An effective crop monitoring system was proposed [12] using Wireless Sensor Network (WSN) to Control water sprinkling by sensing soil moisture. An agriculture solution based on Zigbee technology was proposed to enable automatic monitoring of crop cultivation [6] while [2] used the same technology to sense and monitor the Temperature, humidity and water level of the paddy crop field. A prediction model using Fuzzy logic was developed [13] to predict rainfall through which an effective decision could be made for crop cultivation. A precision farming solution using WSN was proposed in cultivating potato crop in Egypt [14].

A comparative study was done [1] between various applications available with current developed system by considering various aspects such knowledge base, monitoring modules, efficiency and reliability. The system proposed by them overcomes the limitations of traditional agricultural procedures by utilizing water resource efficiently and also by reducing labour cost. Table I gives the technology and its objective in existing system. In the existing method, several authors proposed several methods for automatic crop monitoring but not addressed the issues of big data. In the proposed method, rules framed for the sensed values are compared with the information extracted semantically from various heterogeneous networks to predict high yield crop. The functional framework of the proposed work is explained in the following section.

III. CROP PREDICTION FRAMEWORK

Fig.1 shows functional flow of effective crop prediction using semantic knowledgebase. Various sensors such as Humidity sensors, Temperature Sensors and pH sensors are deployed at farmers' land. The sensed value from various sensors are collected using IoT and sent to the fuzzification function for prediction.

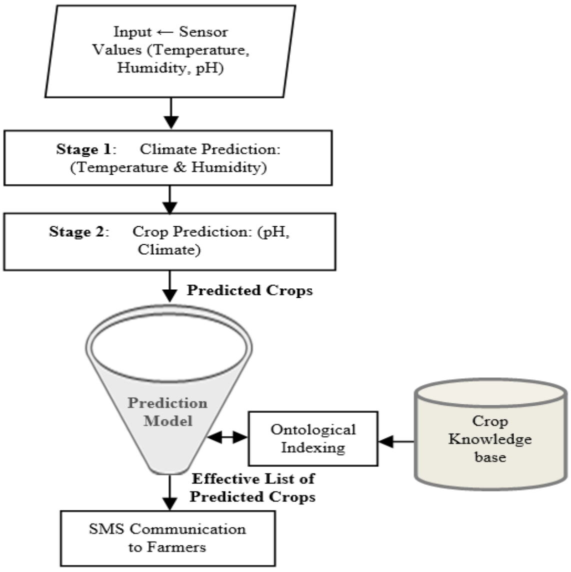

Fig. 1. Effective Crop Prediction Model

The overall architecture of the fuzzy based crop prediction is shown in Fig. 2. There are two stages in fuzzy prediction. Stage 1 predicts the climate based on temperature and humidity. Temperature sensors measure the temperature of the atmosphere over a time and stored in buffer. Similarly, humidity sensor measures the humidity of the soil stored in buffer. Temperature and humidity values are given as input for the climate prediction. Since sensors measure different values for a time interval, the measured leads to fuzzy. Climate prediction involves various steps such as fuzzification, fuzzy rule formation using FAM, defuzzification.

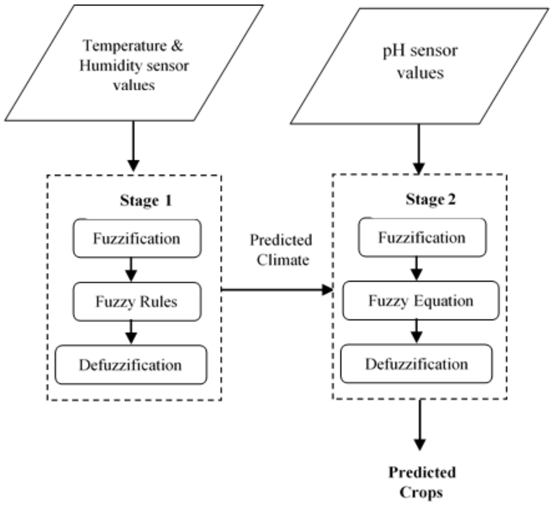

Fig. 2. Crop Prediction Using Fuzzy Rules

Stage 2 predicts the list of crops to be grown based on predicted climate at Stage 1 and pH value of the soil. Crop prediction involves fuzzification, fuzzy equation, defuzzification. List of crops predicted by stage 2 will be tested with the crops knowledge base and predicts the effective list of crops to be grown. The procedure involved in crop prediction using fuzzy logic is given as follows;

Algorithm: Crop prediction using Fuzzy rules

1. Convert Temperature in Celsius to %.
   - *Split the input temperature into two boundary values as Min & Max values.*
   - *Find average of minimum and maximum values.*
   - *Find Temperature in % using the following formula,*

     Temperature = Original value - minimum value/ Average value
2. Normalize temperature and humidity values from 0 to 1 using formula:

   Normalization of (x)=(x-min)/(max-min)
3. Convert it into linguistic variables.
4. Evaluate it using Fuzzy rules to find climate.
5. Predict list of crops to be grown using climate and pH value of the soil.

A. Fuzzy Based Crop Prediction

Fuzzy Associate Memory (FAM) is used to map fuzzy rules in the form of a matrix as shown in Table 1.

TABLE I. SAMPLE RULES FOR PREDICTING THE CLIMATE

Rule 1:	If (temp==high) AND (humidity==*very high*) THEN (Season==summer);
Rule 2:	If (temp ==Moderate) AND (humidity ==Low) THEN (Season==Spring);
Rule 3:	If (temp ==Very low) AND (humidity ==*Low*) THEN (Season==Winter);

The flow diagram for prediction of climate using fuzzy rules is shown in Fig. 3.

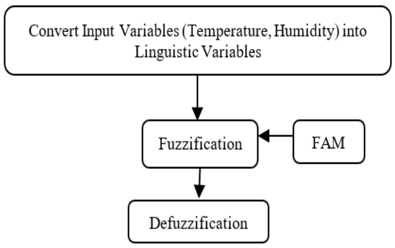

Fig. 3. Flow diagram for Climate Prediction

Fuzzification converts the measured value from the sensors (temperature and humidity) to linguistic variables of fuzzy sets, which consists of 5 tuples such as Very Low, Low, Medium, High, Very High. Fuzzy rules are formed and evaluated by Fuzzy Associative Mapping (FAM) which is shown in Table 2. Fuzzy Associative Mapping is used to reduce the rate of false negatives [14].

TABLE II. FUZZY ASSOCIATIVE MAPPING FOR CLIMATE

Temperature/ Humidity	Very High	High	Moderate	Low	Very Low
Very High	Summer	Summer	Summer	Autumn	Autumn
High	Summer	Summer	Autumn	Autumn	Autumn
Moderate	Summer	Autumn	Autumn	Spring	Spring
Low	Spring	Spring	Spring	Autumn	Winter
Very Low	Spring	Spring	Winter	Winter	Winter

The output of fuzzification is then evaluated by defuzzification to generate its accurate prediction of climate. Defuzzification uses mean of maxima defuzzification method to produce the climate [15]. The climate related variables are shown in Table 3, which gives the list of crops to be grown in respective climate predicted by defuzzification process [16].

TABLE III. CLIMATE RELATED VARIABLES

Attribute	Types	Relative temperature	Relative Humidity	Crops to be Grown
Climate	Summer	Very Hot (32ºC – 40ºC)	Very High to moderate	Millets, Paddy, Maize, Moong, Groundnut, Red Chillies, Cotton, Soya bean, Sugarcane, Turmeric, Barley
	Autumn	Warm Days (> 30ºC) Cool Nights (21ºC – 29ºC)	Low	Maize, Oats
	Spring	Warm Days (> 30ºC) Cool Nights (25ºC – 29ºC)	Low to Moderate	Wheat, Barley, Mustard, Peas
	Winter	Cold (10ºC – 15ºC)	High	Oats

B. Crop prediction using Fuzzy equation

Crop to be grown is predicted effectively based on climate and pH value of the soil. pH sensors are used to measure the pH value of the soil. The type of soil can be identified by analyzing their acidic nature. The list of crops to be grown in respective pH value and soil types is shown in Table 4 and Table 5 respectively.

TABLE IV. PH VALUE AND SUITABLE CROPS

pH Value	Suitable Crops
5.5 – 6.5	Apple, Strawberry
5.5 - 7.5	Tomato, Peas, Corn, Grapes, Carrot
6.0 - 7.5	Onion, Beans, Cabbage

TABLE V. SOIL RELATED VARIABLES

Attribute	Types	Crops to be grown
Soil	Alluvial Soil	Rice, Wheat, Sugarcane, Cotton, Jute
	Black Soil	Rice, Wheat, Sugarcane, Cotton, Groundnut, Millet, Oilseeds
	Red Soil	Potatoes, Cotton, Maize, Pineapples
	Laterite Soil	Tropical crops, Cashew, Rubber, Coconut, Tea, Coffee
	Mountain Soil	Tea, Coffee, Spices, Tropical Fruits
	Dessert Soil	Barley, Millet

Fuzzy equation is used for evaluation. It takes climate and pH as two input variables. Therefore, list of crops to be grown is predicted based on 4 tuples (T, H, pH, S) where T- Temperature, H-Humidity, pH- pH of Soil, S- Type of Soil.

$$S_i = \{A, B, C, D, E, F\} \qquad X = \{A_i, B_i, C_i, D_i, E_i, F_i\}$$

Where A, B, C, D, E, F - Alluvial Soil, Black Soil, Red Soil, Dessert Soil, Laterite Soil, Mountain Soil respectively.

X is a set of crops to be grown in respective soils which are represented as A_i, B_i, C_i, D_i, E_i *and* F_i. Climate is predicted based on temperature and humidity using fuzzy rules and is represented as,

$$f_1(x) = f(t,h) \tag{1}$$

Where t-temperature and h-humidity, x is the crop to be grown and $x \in X$. Crop is predicted based on pH value of soilusing fuzzy equation and is represented as,

$$f_2(x) = f(f_1(x), pH) \tag{2}$$

Where pH - pH value of soil. $f_2(x)$ is fuzzy equation which predicts the crops to be grown. The following fuzzy rule gives the effective list of crops to be grown. Sample rule is given as follows.

$$f_2(x) = \text{Summer AND pH>7.0 then } f_1(x) \cap pH_i \tag{3}$$

The predicted crops using (2) will be used for predicting accurate list of crops to be grown using crops knowledgebase. The data in the crop knowledgebase are clustered based on the ontology and the input query is examined for semantics and expanded using domain ontology. It is then compared with the predicted list of crops from (2) to produce effective list of crops to be grown.

C. Semantic Extraction in Big Data

The agricultural data from various heterogeneous resources are collected and stored in database over several years. The heterogeneous resources consist of information from agricultural researchers, Email, Web Crawling, farmers Profile, which leads to Big Data. These data must be pre-processed to remove unwanted data. During pre-processing, it removes HTML, XML tags and scripting statements from the source documents.

In Big data, the semantic analysis using ontology allows to structure the data from the unstructured data of various resources such as web pages, historical data, which serves as a basis for the implementation of the proposed system for decision support [17]. The semantic analysis gets initiated with the formation of ontology for the information in database based on keyword relevancies using natural language processing. Fig. 4 shows the semantic extraction from Big Data.

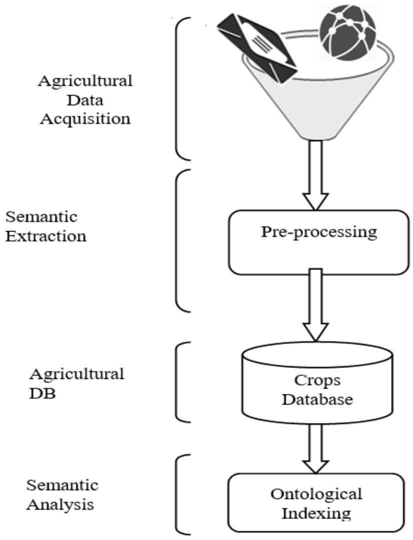

Fig. 4. Semantic Extraction from Knowledgebase

Crop is classified based on ontology, which consists of 3 attributes such as Soil, Climate, and life span which is shown in Fig. 5. Humidity sensors are used to measure the amount of water vapor in air. Temperature sensors are used to sense the temperature level of air from radiation and moisture. Therefore, climate consists of temperature and humidity. pH sensors measure the pH value and is used to analyze the acid level of the soil. Based on this pH value of the soil, the type of soil can be identified. The data in the knowledgebase are clustered based on the ontology and the input query is examined for semantics and expanded using domain ontology. It is then compared with the semantically extracted data to produce effective list of crops to be grown.

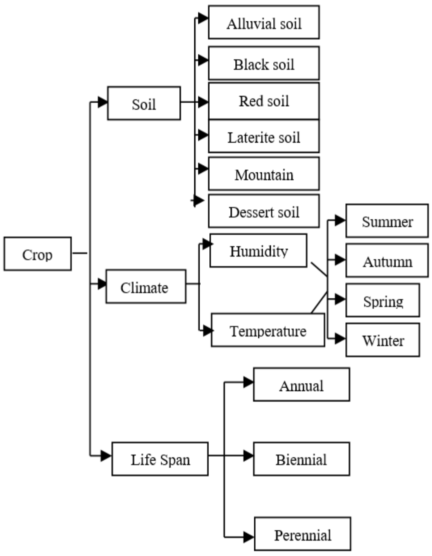

Fig. 5. Ontology Classification of Crops

IV. Results and Discussion

The humidity and the temperature have been recorded periodically for a year to predict the season and the change in the climatic condition. The sensed values are noted and plotted as the graph which is shown in Fig. 6. The values are plotted for the year 2017 - 2018.

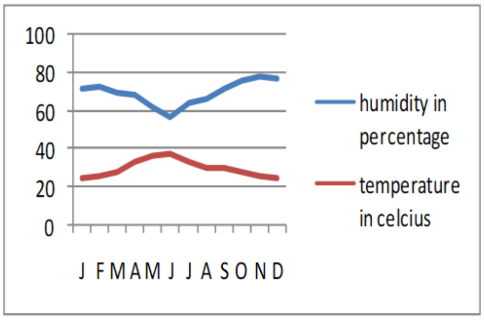

Fig. 6. Humidity and Temperature

The crop to be cultivated is based on pH value of the soil. Fig. 7 shows the p value of the soil, which varies depending on type of soil.

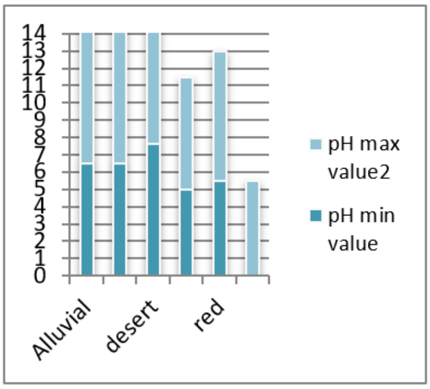

Fig. 7. pH Value Analysis

The semantic retrieval using ontology has been evaluated based on accuracy and time complexity. This proposed system shows high performance when compared to existing system which is shown in Fig. 8. The time complexity is analyzed which is 45 sec for the proposed system and is significantly low compared to existing [14] which has 82 sec. Thus, proposed system is more efficient.

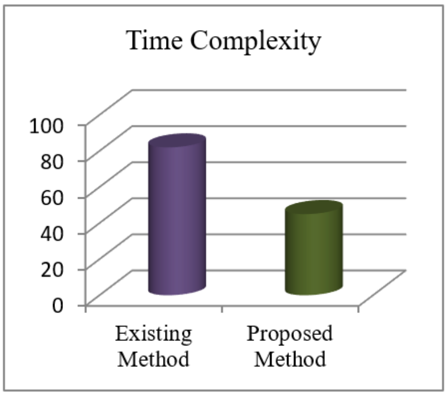

Fig. 8. Time Complexity

V. CONCLUSION

The main objective is to increase the productivity of crop and to provide proper guidance to the farmers to take profitable decisions at right time, throughout the entire farming cycle using IoT technology and machine learning. In this proposed method, computing devices such as temperature sensor, humidity sensor and pH sensor are deployed at different locations in the farm field to measure temperature of the atmosphere, humidity of the soil and pH of the soil respectively. Each sensor communicates with each other through its unique id. The values sensed by these sensors are collected and controlled remotely using Internet of Things.

Initially, Climate is predicted by analysing the temperature and humidity measures collected from respective sensors using Fuzzy Rules. Based on pH value of the soil and Climate, the list of crops to be grown is predicted by comparing it with crops knowledge base. The knowledge base stores agricultural data from various heterogeneous resources over several years. The heterogeneous resources consist of information from agricultural researchers, Email, Web Crawling, farmers Profile, over several years which lead to Big Data. The unstructured information from various resources is structured by semantic extraction, which serves as a basis for the implementation of the proposed system for decision support.

R tool is used to extract the semantic information and stores it in a database. Ontological indexing retrieves the highly relevant information and are then compared with the sets of rules framed for the sensed value to provide suitable list of crops to be grown. The corresponding decision from the knowledge base is sent to the land owner's mobile through SMS. Automatic crop monitoring is also done by controlling the computing devices remotely through IoT. During rainfall, land owners no need to irrigate the land because humidity gets changed. So, water can be saved which in turn consumes power. Also, if the temperature or humidity or pH goes beyond the threshold level, then it generates alert to the corresponding land owners. A fuzzy rule increases the prediction accuracy by reducing the false negatives. Semantic information retrieval in Big data increases the accuracy and reduces the searching complexity by filtering the irrelevant data in the documents.Thus, it produces effective prediction of crop and crop monitoring is also automated to avoid paucity of water.

Therefore, the proposed work overcomes the limitations of traditional agricultural procedures by utilizing water resource efficiently and by reducing the labor cost.

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References

[1] Mohanraj I, Kirthika Ashokumar, Naren J, "Field Monitoring and Automation using IOT in Agriculture Domain", in the Procedia Computer Science, vol. 93, pp.931 – 939, 2016.

[2] K. Sriharsha, T.V. JanardhanaRao, A.Pravin, K. Rajasekhar, "Monitoring The Paddy Crop Field Using Zigbee Network", International Journal of Computer and Electronics Research, vol. 1, Issue 4, December 2012.

[3] Kehua Guoa, Wei Panb, Mingming Lua, Xiaoke Zhoua, Jianhua Mac, "An effective and economical architecture for semantic-based heterogeneous multimedia big data retrieval", in the Journal of Systems and Software, vol. 102, pp.207–216, 2015.

[4] XieNengfu, Wang Wensheng., "Ontology and acquiring of agriculture knowledge", in the Journal of Agriculture Network Information, vol.8, pp.13-14,2007.

[5] Sanjay Chaudhary, M. Bhise, A. Banerjee, A. Goyal, C. Moradiya, "Agro Advisory System for Cotton Crop", Workshop on Networks and Systems for Agriculture AGRINETS 2015 , collocated with 7th International Conference on Communication Systems and Networks COMSNETS , pp 1-6, 2015.

[6] Manijeh Keshtgari, Amene Deljoo, "A Wireless Sensor Network Solution for Precision Agriculture Based on ZigBee Technology", Scientific Research Journal on Wireless Sensor Network, vol. 4, pp. 25-30, 2012.

[7] Maria Rossana C. de Leona, Eugene Rex L. Jalaob, " A Prediction Model Framework for Crop Yield Prediction", Asia Pacific Industrial Engineering and Management System, 2013.

[8] MohdFauzi Othman, KhairunnisaShazali, "Wireless Sensor Network Applications: A Study in Environment Monitoring System", International Symposium on Robotics and Intelligent Sensors, Procedia Engineering, vol.41, pp.1204 – 1210, 2012.

[9] Hemlata Channe, Sukhesh Kothari, Dipali Kadam, "Multidisciplinary Model for Smart Agriculture using Internet-of-Things(IoT), Sensors, Cloud-Computing, Mobile-Computing & Big-Data Analysis", in the *Int.J.Computer Technology & Applications*, vol. 6 (3),pp. 374-382, 2015.

[10] J. C. Kang, J. L. Gao, "Application of Ontology Technology in Agricultural Information Retrieval", Advanced Materials Research, Vol. 756-759, pp. 1249-1253, 2013.

[11] Gelian Song, Maohua Wang , Xiao Ying , Rui Yang, Binyun Zhang, "Study on precision agriculture knowledge presentation with Ontology", AASRI Conference on Modelling, Identification and Control, AASRI Procedia, vol.3, pp.732 – 738, 2012.

[12] N.Sakthipriya, "An Effective Method for Crop Monitoring Using Wireless Sensor Network", in Middle-East Journal of Scientific Research, Vol.20, Issue.9, pp.1127-1132, 2014.

[13] Jimoh, R. G., Olagunju, M., Folorunso, I.O., Asiribo, M.A., "Modeling Rainfall Prediction using Fuzzy Logic", in International Journal of Innovative Research in Computer and Communication Engineering, Vol. 1, Issue. 4, pp. 929-936, June 2013.

[14] Sherine M., Abd El-kader, Basma M., Mohammad El-Basioni, "Precision farming solution in Egypt using the wireless sensor network technology", in the Journal of Egyptian Informatics, Vol. 14, Issue. 3, pp. 221–233, November 2013.

[15] X. Jiang, G. Zhou, Y. Liu, and Y. Wang, "Wireless Sensor Networks for Forest Environmental Monitoring", Innovations and Trends in Environmental and Agricultural Informatics, pp. 2-5, 2010.

[16] S.Sangeetha, M.K.Dharani, B.Gayathridevi, R.Dhivya, P.Sathya, "Prediction of Crop and Intrusions using WSN", Proceedings of 3rd International Conference on Advanced Computing, Networking and Informatics in the series of Smart Innovation, Systems and Technologies, Vol. 44, pp 109-115, 2015.

[17] Y. Zhang, "An Excellent Web Content Management System", In the International Conference on Multimedia Technology, Hangzhou, pp. 3305–3307, June 26–28, 2011.