Design and implementation of WSN for precision agriculture in white cabbage crops

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***Abstract*—This research presents the design and implementation of a precision agriculture system using sensor networks as the basis in precision agriculture for farmers of white cabbage (Brassica rapa ssp. Pekinensis) in Panama/China with the aim of transferring knowledge and mitigating the effects of the soil and climate change on crops of white cabbage. Finally we found the optimal ranges to improve productivity and avoid losses due to uncontrolled agroclimatic variables such as relative temperature, soil temperature, relative humidity, soil moisture and luminosity.**

Keywords— Precision Agriculture; Wireless Sensor Network; automation; geostatistics; production

I. INTRODUCTION

The information and communication technologies (ICT) can be used to support climate-smart agriculture, which is defined by actions that "look to increase sustainable productivity, strengthen resilience of the producers, reduce greenhouse gas emissions and increase carbon sequestration, while strengthening food security and ensuring benefits for the environment" [1].

One of the objectives of the climate-smart agriculture is adaptation, for example, how the farmers feel about the need to change agricultural systems in response to climate change? This "transformative adaptation" is much more advanced in developed countries such as Australia, however, it also presents a high potential in developing countries [2].

This paper organized as follows. Section 2 presents the problem, Section 3 a Solution and Finally, Section 4 the Results.

II. PROBLEM

Currently, the technologies applied in Latin American and Asian agriculture is more artisanal which does not allow full development of this sector; therefore you cannot get a top quality product. You need to apply new technologies in this field with the aim of obtain a qualitative and quantitative change in the production, to generate a better standard of life for both, the people involved in this activity, and consumers.

Climatic factors such as temperature, solar radiation, relative humidity, soil moisture, wind, etc. influence the performance of seasonal crops, as they affect plant growth and physiological processes related to the formation of grain. These factors also affect performance indirectly increasing damage caused by pests and diseases. The recommended water or soil moisture level is essential to maintain proper nutrient management, weed, of pests and diseases. Transient crops grow in damp, warm environments where insects - pests and also thrive damage the crop.

III. SOLUTION

The solution to the problem was design a system of precision agriculture at low cost call ***SmartNod***e. That it is a platform software and hardware that allows monitoring the agroclimatic variables for optimal crop development.

Figure 1. Smartnode

To build the proposed system, The device should be: 1) Low Cost, 2) Distance: about 2 km from the crop to the data center, 3) Reliable: transmits collected data correctly and quickly to the central unit, 4) Robust: endures all types of weather conditions, 5) Connectivity: Local networks, internet and mobile application (app), 6) Efficient: consumes a very minimal energy during its operation, and 7) Eco-friendly: function using a battery, recharged using solar energy. Based on these specifications, the best components were chosen, so they suit those specifications. The project is divided into three main parts: Hardware node, Wireless Sensor Network, and finally the software part that includes a reading from the USB port program and a website / App android.

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A. *Hardware Smartnode*

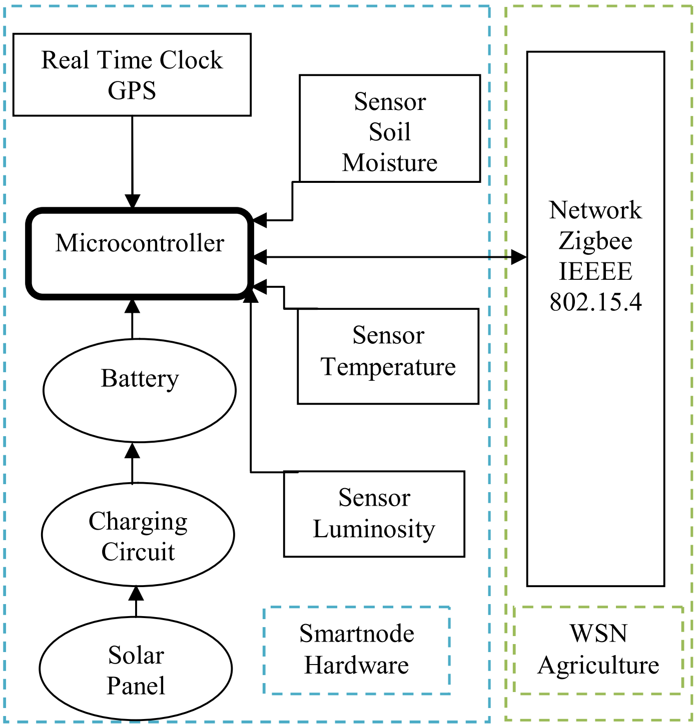

Figure 2. Hardware Smartnode

One of the most important features of the node it's the portability, which is why it is vital the node feeds, because it was decided to make the use of batteries and renewable energy as it facilitates handling in the field. The microcontroller used in the system is the ATmega328p, which is the main component responsible for acquiring, sending, and receiving data.

B. *Zigbee network topologies*

For the development of this project the ZigBee protocol was selected mainly for the low power consumption, which is very important in the type of applications considered in this project, because the location of the nodes demand long periods of time without them they can be tapped.

The system based on WSN (Wireless Sensor Network) has the characteristic of having specific measurements and estimates their values to a particular radio, depending on the network topology. The sensors act in an autonomous way (renewable energies), depending on the measurement object of study, cultivation, also can be sampling times for data acquisition.

The network topology refers to how it's connected and the way how the various devices that make up a network communicate. The network topology wireless sensor used is showed in the following figure:

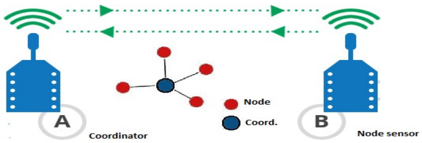

Figure. 3. ZigBee network topology

Star topology Communication is only between devices and the network coordinator. If the network coordinator should fail the whole network would be out of operation, i.e. have a single point of failure.

C. *Connectivity Architecture and Software and acquisition program*

Connectivity is vigorous for this project because in Latin America there are places without internet connection or cellphone network, for this purpose, two network architectures were designed, the firstly: a network allowing monitoring the crops all times with the implementation of a local server and a database. Secondly, in the case of connectivity in the field, i.e. cellular network or internet, monitoring of environmental variables and soil can be tracked in real time, using a website and time distance mobile application.

The system works via cellular network, with a sim card chip for data sensed by the network, they can be sent with a sampling of a one hour cloud server used for receiving data.

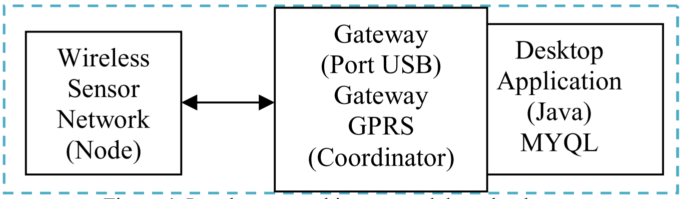

Figure 4. Local server architecture and data cloud.

IV. RESULTS

Project validation white cabbage crops in Cocle, Panama was performed. This pilot presents the following results:

Figure 5. System of precision agriculture in crops of white cabbage in the Panama case.

Characteristics of wireless sensor networks:

- Distance between the gateway and a sensor: 1.6 Km
- Numbers sensors in Panama/China: 6 Node Sensor, 1 Coordinator
- Sampling rate: 30 minutes
- Active current: 160 mA
- Idle current: 39mA

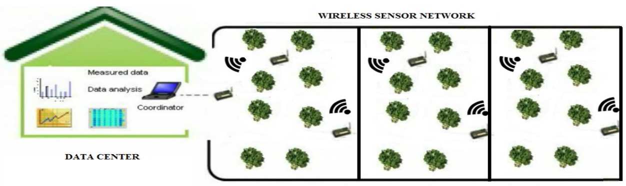

Figure 6. Project scenario

For the implementation of the algorithm of estimation selected variables measures were analyzed. The temperature and humidity were obtained in the field of study, which were randomly taken to determine their behavior in this ground and obtain the optimal estimate precisely at the points were the samples did not perform. This Kriging estimation algorithm was implemented in the Matlab toolbox mgstat for variables geostatistical analysis. Figure 7 observes the distribution of samples identified by the blue dots within the field of study, which represent the nodes in the network of sensors monitoring the variables. The algorithm receives the coordinates X and Y of the total area of the crop and the values of the variables measured by each node. Blue dots indicate damp ground and red dots indicate dry land. For the correlation of variables carried out was an experimental design factorial of 4 variables, in order to find the relationship of the variables of soil and environment on productivity. More than 10000 descriptive statistics data is managed to find the different means, variances and standard deviations by harvest could be obtained thanks to the implemented precision agriculture.

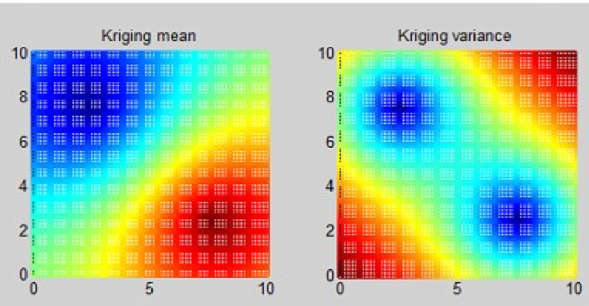

Figure 7. Data acquisition system and soil maps

Finally, in general terms, economic theory showed that production function is an analysis tool that allows the relation of the quantities of factors that are required (X) and the way in which they are combined to produce a particular good (Y). When linear regression is applied it predicts the behavior of Y using X then the simple linear regression model is of the form (1) [3]:

$$Y_{t=} \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_p X_p + \varepsilon \quad (1)$$

Where Y is called the response variable or dependent, X is called the predictor or independent variable and β is the slope of the regression line and ε is a random error, which is supposed to have a mean of 0 and a constant variance of σ2.

TABLE I. REGRESSION ANALYSIS PANAMA

Environmental Temperature ºC	Relative Humidity (%)	Soil Temperature ºC	Soil Moisture (%)	Yield (pounds)
29.32	58.41	26.93	83.01	240
27.00	59,32	25.38	97.70	240
28.57	55,56	26.42	83.99	240
29.46	61,30	25.80	94.30	240
27.61	66,31	26.42	84.55	247
29.09	54,80	26.02	84.46	280
28.49	53,14	25.68	87.25	200
28.22	57,22	27.19	44.87	262

The regression equation is:

$$P = 131 + 5.1(ET) + 1.57(RH) - 2.7(ST) - 0.65(SM) \quad (2)$$

P= Productivity
ET= Environment Temperature
ST= Soil Temperature
SM= Soil Moisture

One of the most important results to see is the main effects of each factor or variable with respect to the average productivity.

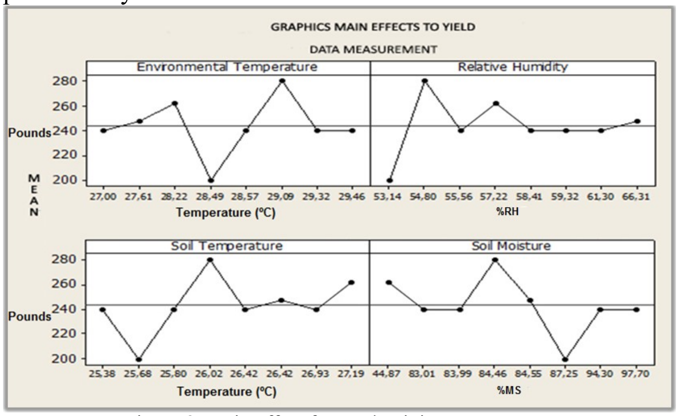

Figure 8. Main effect for productivity Panama case

Figure 8 shows the behavior of the average of each variable from the productivity. It is important to see the main effects of each factor or variable with respect to the average of productivity. In the case of soil moisture, sometimes it was important to keep a range of saturation in contrast to the relative temperature, more temperature is less productive. Variables like relative humidity between damper environments are much better in terms of productivity. Finally the temperature of the soil is an inversely proportional incidence to the moisture of the high temperatures soils; its effect against productivity its low gain.

In China's case we studied the production of ***(Brassica rapa SSP.. Pekinensis)*** an organically registered farm in (CSA) a Community Supported Agriculture, which is one of the most crucial ways of sustainable agricultural development in recent years.

Tests with two scenarios were developed. For the pilot of China's case we developed 2 replicas, one was at the Fujian Agricultural and forestry University and the other was in the CSA farm in Fuzhou.

TABLE II. REGRESSION ANALYSIS CHINA

Environmental Temperature ºC	Relative Humidity (%)	Soil Temperature ºC	Soil Moisture (%)	Yield (pounds)
29,13	50,75	27,90	87,45	95,0
27,02	43,32	24,65	91,71	87,0
21,70	41,80	20,02	79,64	152,0
20,61	54,35	40,57	47,95	152,0
16,71	50,27	16,01	93,40	134,3
16,80	36,21	16,06	97,03	36,0

In this analysis you can notice and validate using the regression manifold found by experimental data, in winter conditions, the variable object of study such as soil moisture to a range of saturation does not affect the productivity in comparison with the pilot in panama, was vital their control. Accordingly, in winter conditions for white cabbage irrigation periods are almost zero, since factors that affect the productivity were the soil temperature and relative humidity.

The regression equation is (3):

$$P = 501 + 6.18(ET) + 4.72(RH) - 11.4(ST) - 5.67(SM) \quad (3)$$

P= Productivity
ET= Environment Temperature
ST= Soil Temperature
SM= Soil Moisture

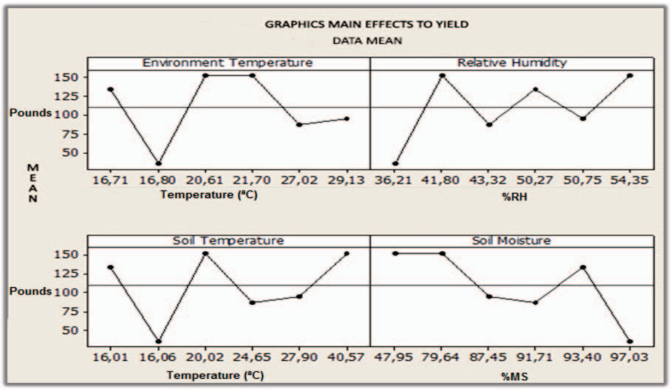

Figure 9. Main effect for productivity China case

After analyzing each scenario of the test pilot it was necessary to generate traceability, the comparison of variables under conditions previously considered such as climate and the variety of white cabbage etc.

According to the previous figure, we can see that in the pilot of Panama the temperature was 29.09 °C, presenting the maximum peak performance. The pilot of china's maximum peak of yield in terms of temperature occurs in a range of 20.61 C - 21, 70 ºC (winter conditions).

With respect to relative humidity it presents a similar behavior, but with different weather, in Panama 54.80% was the maximum peak performance and China it was 54.35%.

With respect to soil temperature similar behavior arises in the two pilots, but with the difference of maximum peak in Panama's pilot occurred at 26.02 ° C and China 20.02 ° C.

The soil moisture was an important variable that we took into account, and was not a random factor such as temperature and relative humidity. In this case, the pilot of Panama the highest peak was at 84.46%, and if we see in the practice the vegetables required lots of water, so it must prevent over-saturation of moisture. When a plant is saturated, often the plants are stressed.

TABLE III. RANGES OF VARIABLES FOR A GOOD PRODUCTION

RANGES OF VARIABLES FOR A GOOD PRODUCTION		
Variables	**Pilot Panama**	**Pilot China**
Soil Temperature	**25.80ºC – 26.42ºC**	**18ºC-20.02ºC**
Relative Temperature	**28.57ºC – 29.32ºC**	**20.61ºC-21.70**
Soil Humidity	**83.99% - 84.55%**	**47.95% - 79.64%**
Relative Humidity	**54.80% - 66.31%**	**50.75% - 54.35%**

V. CONCLUSIONS

It is very important to apply information and communication technology to the Latin American countries and Asia, because we have a lot of agricultural production. Currently, they are signing free trade agreements where product quality plays an important role, therefore it is imminent the automation to mitigate the effects of climate change that is a global problem.

What cannot be measured cannot be controlled; it is the main philosophy that is implementing this project. It is vigorous significance to produce knowledge and act, depending on the data that is coming in real time to make speedy corrections. According to the rates of literacy of the farmers, the use of graphic records is imminent with visual alarms, so there is a full understanding between the user and the technology.

Technology can provide low costs, when small and medium farmers have the same opportunity to introduce technology processes as the big producers and agricultural industries.

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