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Proposal of an Intelligent Agricultural Maintenance System for Crop Production in the Caribbean

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Abstract: In agriculture, irrigation is a crucial component of crop production. Many Caribbean countries have both a "dry" and "rainy" seasons. In the dry season rainfall is scarce and irrigation must take place in order to provide plants with the necessary moisture required for successful growth. Ina rainy season excessive rainfall may result in waterlogging of soil. Many farmers however apply irrigation without measure of the actual amount of water applied and the optimum requirements for plant growth. This may lead to over-irrigation/under-irrigation. This paper entails the proposal of a scalable intelligent agricultural maintenance system to aid crop production in the Caribbean. In the rainy season excessive rainfall may result in too much moisture being applied to land so this system will also be capable of indicating to administrator the status of soil moisture during rainfall.

Keywords: FPGAs, Agricultural Technology Adoption, Smart Agricultural Systems, Intelligent Agricultural Systems, Smart Irrigation, Precision Agriculture, Agricultural Fertilization

1. Introduction

[10] indicates that climate change is one of the most serious challenges faced in agriculture while at the same time agriculture is blamed for contributing to climate change because of the use of pesticides, land use practices and fertilizers. Climate change may result in droughts, adverse weather conditions, changing rainfall patterns, etc. This results in reduced production and productivity. This ultimately affects the food security of billions of people around the world, particularly in Africa where the livelihoods of over 70% of the population is dependent on agriculture [10].

In the past six decades the upgrading of agriculture policies was geared toward an increase in food production. This policy upgrade resulted in an increase in use of pesticides, inorganic fertilizer, machinery etc. The methods used for weed, pest and diseases control have changed from the safe use of natural, cultural and biological control to the use of pesticides, weedicides, etc [17]. The use of natural sources of nutrition such as compost, manures from livestock and even the strategic use of nitrogen fixing crops such as pigeon peas has been replaced by the excessive use of inorganic fertilizers [17]. The is also an increase in the use of technology in agriculture. The use of technology in agriculture can not only significantly increase agricultural sustainability and production but also reduce wastage of available agricultural resources such as access to water, fertilization, all in the long run resulting in a cost saving. The use of technology can also reduce the cost associated with human labour.

This paper serves to propose an intelligent agricultural maintenance system capable of aiding farmers of Trinidad and Tobago and the Caribbean by extension in smart and precision irrigation of their crops. This system should not only significantly reduce wastage of water but also significantly minimize the use of human resources in the actual process of irrigation. It makes it very possible for these same human resources to focus more time on strategic planning for their agricultural business.

2. Literature Review

[4] evaluated the performance of export of agricultural produce during the period 1980-2004 for Caribbean countries which have borrowed from the Caribbean Development Bank, excluding territories dependent on the United Nations. [4] also assessed the issue of food security and dependency. [4] concluded that there is an urgent need for the transformation of agriculture in the Caribbean region with the use of technological advancements to guarantee diversification in high value, dynamic and processed export markets. This will result in a substantial earning of foreign exchange for the sustainable development of countries in the Caribbean region [4].

[7] reviewed the use of precision agriculture technology in cotton farming. In precision agriculture the variability of certain aspects of soil and crops is assessed and information is gathered for use in site-specific management practices for optimization crop production. [7] assessed the effects of various regional characteristics on the intensity of precision agriculture technologies utilized by cotton farmers. At the end [7]

reaffirmed the importance of technology in agriculture and the need to keep innovating to sustain agriculture, specifically the cotton industry.

[9] presented benefits of agricultural innovation to peasant farmers in rural areas in China. Peasant farmers in rural areas must afford to adopt agricultural innovation in order to increase productise and revenue in agriculture [9]. [9] indicates that technology innovation in agriculture is a great consideration for avoiding potential food crisis in China. [9] reported that with the involvement of technology innovation and advancements such as the sue of hybrid seeds, fertilizers and pesticides the annual grain output in China increased from 446 million tons in 1990 to 570 million tonnes by 2011. Although technological and scientific advancements benefit China at large, peasant farmers in poor rural area have not as yet adequately benefitted from them because technological and scientific adoption is expensive [9]. As such [9] suggest that movement policy should be geared towards assisting these peasant farmers adapting to technological and scientific advancements. This will further increase the agricultural output of the nation. [9] recommended an investment by governments towards research and development in agricultural technology for the upliftment of the sector.

[10] indicates that one of the major environmental challenges faced in agriculture is that of inconsistency of rainfall. This is immediately linked to relatively low rainfall or frequent drought spells or in worst case scenario high levels of soil erosion. All instances may either result in over-irrigation or under-irrigation. In light of this [10] stresses on the need to adopt good production practices and sustainable production systems to uplift agriculture.

[15] evaluated the impact of improving farming techniques in the Gaza of rural Mozambique on agriculture in the area. The impact of a group-based approach towards the adoption of technology in agriculture was evaluated. [15] indicated that the intervention of improved farming techniques including the adoption of technology was successful in increasing the number of households in rural Mozambique in participating sustainable farming practices. According to [15], the region is vulnerable to drought. Since water for crop production is completely sourced from the rain, drought is the most common factor adversely affecting food security and revenue from agriculture. Heavy rainfall can result in floods which can wash away top-soil, hence affecting agricultural revenue generation [15].

[16] presented a qualitative analysis on the adoption of innovations in agriculture. The agricultural sector is faced with a need to increase production of food reserves to support the nutritional needs of an expanding population. [16] stresses the need to adopt approaches to carrying out operations inherent in the agricultural sector. To do this the sector must invest in research and development to enable technology adoption. Agricultural technological innovations will provide limitless possibilities to help challenges faced in labour, market fluctuations, food supplies for the population etc. [16] presented a list of drivers for the adoption of technology innovations in agriculture including the use of information and communication technologies (ICTs).

[17] discussed the importance, usage and role of modern technology adoption in agricultural improvement. [17] implied that driverless tractors and a variety of other agriculture machinery containing GPS and electronic sensors may prevail in that in the future of agriculture. [17] also discussed the use of crop sensors in aiding farmers in the application of fertilizers in a very effective way in order to maximize nutrient take-up by plants. [17] also presented the monitoring and controlling of irrigation system via mobile technology and cameras. Smartphones gave the farmers the ability to control the switching on and off of irrigation systems using electronic devices to avoid human intervention in this respect. [17] claims that use of modern technology has resulted in a significant increase in the agricultural outputs of the top 15 countries that utilize such technology and has contributed substantially to the GDPs of these countries.

[18] encouraged intensifying sustainable crop production via modern farming practices and the use of technology to guarantee resilient crop production. To do this institutional environmental and social principles must be taken into consideration. [18] encourages agricultural management strategies like conservation agriculture where disturbance to the soil is minimized. [18] also provides support to farmers in progressing with integrated pest management systems which depends on natural pest control and more effective use of fertilizer and water resources for ensuring soil is healthy and adequate for crop growth.

3. Contribution of Research

The general trend recognized in the review of existing literature is that many researchers have recognized the need for technology adoption in sustainable development in the agriculture sector. There is a need to automate all processes in agriculture which originally were executed by human elements. This paper contributes to the agricultural sector in proposing intelligent systems capable of effectively solving issued faced in crop production. One major issue identified in the review of literature is that or adequacy of water for irrigation of crops. Droughts many times result in under-irrigation, while excessive rainfall and stormy weather may result in over-irrigation and in worst case scenarios, flooding which affects the topsoil. Both scenarios adversely affect crop production. The contribution of this paper is the proposals of an intelligent agricultural maintenance system for crop production in the Caribbean. This intelligent agricultural maintenance system will have the following features:

(a) Measures soil moisture and transmits real-time information about soil moisture using GSM modem from a variety of locations within the portion of land to administrator for analysis.
(b) Capable of allowing setting of optimum moisture level for different crops.
(c) If moisture level falls below the minimum threshold required, then an irrigation system is turned on for that portion of land and kept on until optimum moisture level restored.
(d) If moisture level above max allowable then warning messages to be send to administrator using GSM modem for intervention for removal of excess moisture.
(e) Must possess a graphical user interface on the administrative side for displaying all messages, warning and information sent by agricultural maintenance terminals in the field for manual control of switches, actuators which resolve moisture issues if there is need for manual intervention
(f) System is portable and capable of being powered via batteries or the 12V outlet of a vehicle (Cigarette lighter)
(g) Must be scalable, hence allowing addition of more terminals depending on the size of parcel of land under crop production.

4. Description of Proposed Agricultural Maintenance System

The proposed intelligent agricultural maintenance system consists of several segments. A parcel of land under cultivation may be divided into several sectors or segments depending on the irrigation requirement of the crop to be cultivated. One (1) Slave Terminal (ST) will be placed on each sector of land. As such if the parcel of land is divided into 20 sectors then 20 slave terminals would be required. The system also consists of one (1) Master Control Terminal (MCT) and one (1) Central Administrative Terminal (CAT).

The slave terminal represents the sector of land which it is assigned to. The purpose of a slave terminal is to monitor soil parameters such as soil moisture, PH, nutritional content for the sector of land its assigned to and report any deficiencies and other issues to the master control terminal via communication using a long-range XBee wireless communication network. The MCT in turn analyses the issues experienced on the STs and determines the best corrective action to resolve the issues faced. The MCT then sends commends back to the ST which will utilize electronic and mechanical devices existing at each ST for correcting the issues. In all events the MCT reports the issues faced at the STs to the CAT for recording purposes only. If any situation arises that the MCT cannot resolve and needs human intervention, then the MCT sends a request for resolution (RFR) request to the CAT which will then attract human intervention in that respect. The MCT communicates with the CAT via a GSM mobile network which means that it is very possible for automatic text messages or even calls to be made to the CAT from the MCT. Figure 1 below gives the concept diagram for the Intelligent Agricultural Maintenance System.

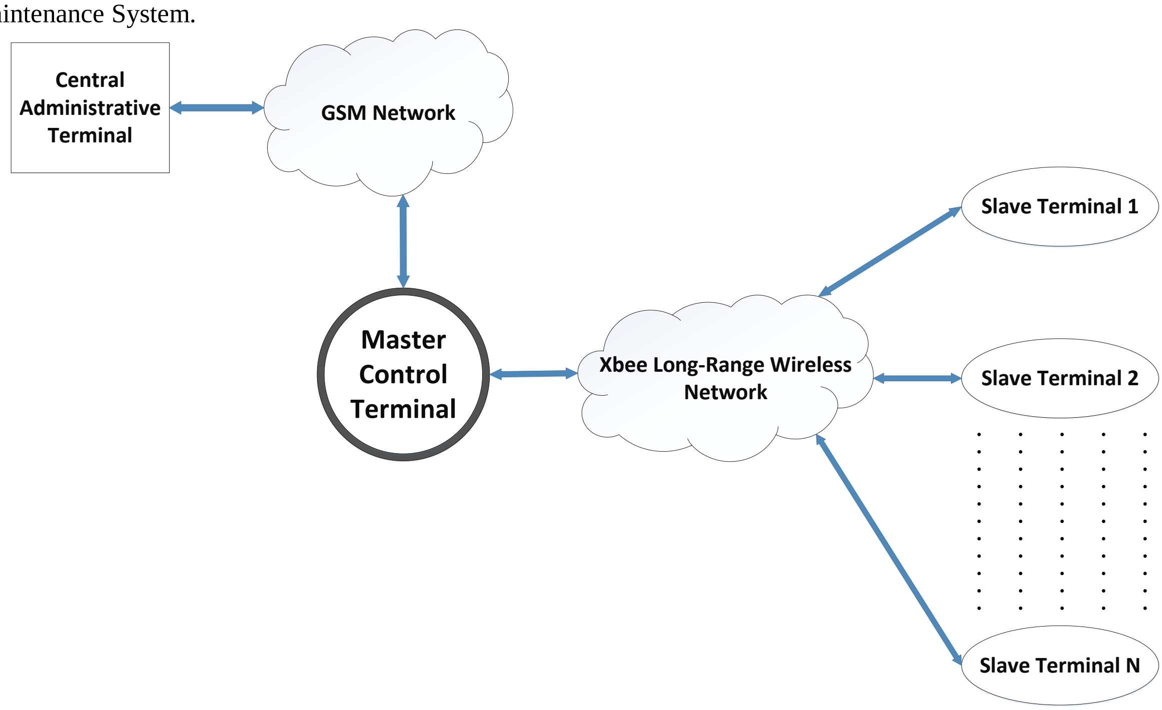

Figure 1: Concept Diagram of the Intelligent Agricultural Maintenance System

In this paper the intelligent agricultural maintenance system focusses on aiding crop product in the aspect of soil irrigation so each ST will focus on soil moisture monitoring. Each ST will consist of the following:

(a) A programmable logic device (PLD) such as a Field Programmable Gate Array (FPGA) or a Configurable Logic Device (CPLD).
(b) Calibrated soil moisture sensory component.
(c) Irrigation Actuator component.

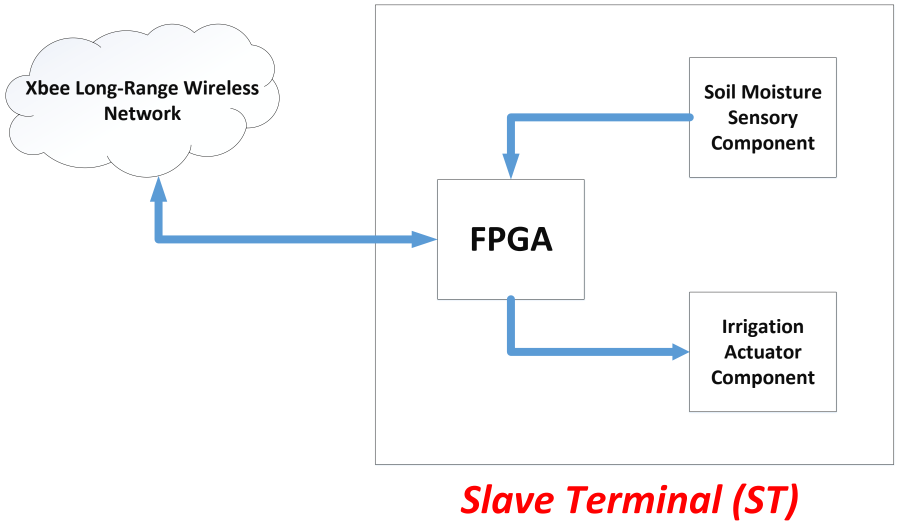

Figure 2: Concept Diagram of the Slave Terminal (ST)

The soil moisture sensory component comprises of physical sensors and analog-to-digital converters (ADCs). The soil sensors acquire the soil moisture signal after which the ADCs convert that analog signal to digital format before passing it to the FPGA for processing. The FPGA analyses the information passed on from the soil moisture sensory component to determine if the soil moisture is adequate or not. If its adequate, then there is no need to cause alarm. However, if its inadequate it sends a warning-information message to the MCT via the XBee long-range Wireless Network.

The MCT which consist of an FPGA will interpret the warning-information message from the ST and then reply with an action-information message which the FPGA on the ST will decode. The FPGA will then interact with the irrigation actuator component which results in the beginning of the irrigation process. Hence moisture will be added to the soil and while this is done the soil moisture sensory component will determine if soil moisture is returned to optimum condition. When this is done the FPGA on the ST will stop the irrigation process. As a result, this intelligent agricultural maintenance system guarantees the swift and efficient monitoring and regulation of soil moisture for crop production without the intervention of human resources.

To ensure that human elements are kept up to date with all activities occurring inside the intelligent agricultural maintenance system the MCT updates a graphical user interface ion the CAT. The CAT can also be used to reconfigure the system so that it can be adapted for use in other crop production schemes. The soil moisture can be regulated for any crop type and any soil type using this system. All it requires is the introduction of new parameters for that new crop or soil scheme.

Since the parcel of land may contain numerous sectors and as such multiple STs will exist. Because of use of FPGA technology it is very possible to process the needs of multiple STs at the same time. The system is scalable and hence can be adjusted to be used on any size of land.

The system is portable and capable of being powered via batteries or the 12V outlet of a vehicle (Cigarette lighter). The system can make better use of natural resources by upgrading it to make use of solar power Solar powering capabilities can be included in both MCT and STs so that batteries can be back-up power supplies. This can also result in a reduction in the cost of the system.

5. Conclusions

The proposed intelligent agricultural maintenance system can substantially aid crop production in the Caribbean. This system ensures that crops will experience their optimum moisture conditions. The system can be further upgraded to incorporate the regulation of other parameters such as soil PH and soil nutrition. Finally, the system can be upgraded to incorporate flood monitoring capabilities which will inform the CAT of the imminence of flooding on the parcels of land under crop production.

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