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Smart Irrigation for Yellow Pepper Production using GPS and GSM Technologies

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ABSTRACT

Background: Yellow pepper production is the major farming activities of women in Nsukka senatorial zone of Enugu state of Nigeria. The main sources of irrigation for this group of farmers are tanks and under-ground tanks that are artificially supplied with water in their different farms, since natural sources of water are not always available. These women mostly use their buckets or other containers to fetch water from tanks. They continually monitor the water level of their tanks in all their farms to know the best time to refill those tanks and also, they irrigate their crops manually. With the continuous demand of this variety of pepper, this current approach is quite challenging, not sustainable and highly labour intensive. Hence, there is an urgent need to boost production and address those challenges and difficulties associated with the current irrigation method through Internet of Things and other innovative techniques. The aim of this paper is to use a smart system to monitor and control soil moisture, temperature and water level in the tank. The paper equally aims at detecting the location of the farm where tank that is to be refilled is placed.

Methods: Simulation and experimental methodology was employed in this research. The components of the proposed system include sensors, GSM, GPS, water pumps and microcontroller. Ultrasonic sensor monitors the water level in the tank, moisture and temperature sensors monitor the soil moisture and temperature, water pump sprinkles water on the crops, GPS provides the location of the tank, GSM sends message when the need arises while the microcontroller takes decision and coordinates the functioning of the entire system

Result: The research produced a system prototype that monitors and controls the usage of water on yellow pepper crops and refilling of water tank in the farm.

Key words: Crop production, GPS, GSM, Smart irrigation, Yellow pepper.

INTRODUCTION

In Nigeria, conventional farming approach is still the most widely used approach by farmers despite increase in population and high demand for food. For instance, the Nsukka yellow pepper which is very special specie of pepper with nice aroma and flavour is still being produced through conventional means despite its high demand both within and outside the country. The production of Nsukka yellow pepper is now the major farming activity of majority of the rural women in the Nsukka zone (Onwubuya *et al*., 2008). Investments in agriculture through technological progress have played a vital role in food supply, sustainable production (Pardey *et al*., 2014) and food security (Balş, 2010). Yellow pepper as a crop is sensitive to water content of the soil. That is, it requires optimal water supply to have an improved yield. The conventional farming approach is characterized with hard labour, high time consumption, poor yield and insufficient food supply for the teaming population in the country.

Today, what is needed in farming and agricultural sector is an innovative idea and technological advancement to close the supply gap through high yield, efficiency and environmental protection. The application of advanced technology in agriculture should be a strong force behind improved crop production at low cost and fewer resources. Smart technology has transformed many facet of our life such as health, automobile, home automation, industry, thus it is reasonable enough to advocate its application in agriculture. Internet of things has becomes an important tool for predictive maintenance (Donca, 2016) or an intelligence assurance policy geared towards improving products and services quality through process optimization.

The production of yellow pepper is often done in the dry season than in the rainy season. The main reason for this is because water supply to the crops is always in excess during rainy season which affects the crop and reduces its yield. Therefore to maximize production within the dry season, there is need to automate the irrigation process and regulate water supply to the crop by using sensor and other IoT facilities.

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This paper aims at designing and simulating a system that is capable of monitoring the soil moisture and temperature, regulates the supply of water to yellow pepper crops using sensors, pumping units, microcontroller, GSM and GPS modules. The system also has the ability to inform the farmer on the appropriate time to refill a tank and the particular farm where tank is located. Leveraging on IoTs technique will reduce waste, enhance productivity and improve the overall efficiency of the crop production processes.

The estimated turnover value of N12 billion would be obtained from the cultivation and export of Nsukka yellow pepper. This development he said would promote the nation's agricultural history and potential (Ossai, 2017). Moreover, Director General, Nsukka Chamber of Commerce, Mr. Dan Oche, at a meeting with farmers in Nsukka, said that their target is to produce the yellow pepper in commercial quantity such that about 80 per cent of it would be exported to Europe and America (Ikem, 2018).

The present approach for the production of yellow pepper in Nsukka has enormous challenges. Nsukka Yellow pepper is very sensitive to certain climatic conditions such as heavy rain. As a result of this, the best production period for the farmers is dry season. Farming in the dry season requires irrigation which is very difficult and stressful because of the manual method used, hence requires smart irrigation method.

MATERIALS AND METHODS

Review

The concept of irrigation dates back to 3000 BC (Agriculture and Urban Life in Early Southwestern Iran on JSTOR, 2022) cited in (The Domestication and Exploitation of Plants and Animals, 2022). Irrigation is an act necessitated by domestication of farm products with the purpose of either increasing yield or growing products that are not supported by the environment type of a place. Many researchers have experimented and therefore expounded the irrigation concept, from the era of its implementation without elaborate technology, to the introduction of mechanization, digitization and presently, automation, which refers to the use of intelligent systems in the present day industrial revolution (IR).Various researchers study effect of one irrigation method or a hybrid of methods, implemented at different stages of plant domestication. The authors in (Kumar *et al*., 2021) sought to find the effects of various irrigation methods on chickpea. Their method involved using basin irrigation method as control and comparing plant parameters grown using drip irrigation method. Ramana Rao *et al*., (2016) compared the performance of pea under conventional flood irrigation method, to its performance under micro sprinkler and drip irrigations. They found that, while the conventional flood method supplied the highest water to the plant, it performed the least with respect to yield. Different methods are implemented to automate such control measures as irrigation scheduling (Ahmad *et al*., 2015; Brijbhooshan *et al*., 2015; Brar *et al*., 2016), irrigation level (Kumar *et al*., 2017; Arun *et al*., 2018), irrigation regime (Gholamhoseini *et al*., 2017), irrigation water quality (Murugesan *et al*., 2018) *etc*.

Arif *et al*., (2017) presented an Arduino based smart irrigation System. The system described how irrigation can be automated without constant vigilance. In their work, the description of how water can be conserved and supplied to the plant based on plant water requirement was discussed.

Ashwini (2018) built a smart irrigation with the target of conserving the monsoon water which is the main source of irrigation for farmers in India. Sensors were used to obtain the values of soil moisture, temperature and air moisture. The data received from sensors are sent to server database using wireless transmission.

A study on Smart Irrigation System using IOT was made by Priyadharsnee and Rathi (2017). The main feature of their research was to know how smartly and automated the system can control the supply of water to the agriculture field according to their need. Notifications are sent on the farmer's mobile application using Wi-Fi Relay Module and Arduino UNO R3.

In Boby *et al*., (2019), the researchers employed the use of IoTs to solve the problem of shortage of water supply to the plant. Temperature sensor and Soil moisture sensor were used to obtain the values of temperature and soil moisture respectively. GSM was also integrated to the system for sending field notifications to the farmers from Arduino uno.

Kumar *et al*. (2019) focused on the design and implementation of smart irrigation and tank monitoring. The system makes the farm irrigation and monitoring of the tank to be automated. Temperature sensor, soil moisture sensor and ultrasonic sensor were used for the design.

Knowledge gap

GPS was incorporated in this work which was not considered in the reviewed work to provide the location information of the particular tank that is to be refilled. To guarantee continuous working of the proposed system, solar-based system will be a better option for recharging the battery which was not considered in the existing system.

The system prototype was built in the Department of Computer Science, University of Nigeria, Nsukka between November, 2021 and January, 2022. Simulation and experimental research methodologies were used in this project. In this section, we carried out analysis of the existing and the proposed system with the view of finding out drawbacks or problems with the existing system and then improve on them. Later, the proposed system was designed and simulated.

Existing system

In the existing systems, sensors and GSM are used to monitor the field and transmit message. The existing system does not have means of identifying the location of tank. It also failed to provide means of recharging the system.

Proposed system

The proposed system in addition to features in the existing system makes available the location of the tank with the aid of GPS. Secondly, to ensure continuous power supply, solar-based power system will be used in recharging the system.

System design

The proposed system circuit was designed in Proteus 8.0, using the appropriate tools available and the corresponding software.

Simulation

An arduino program was written in arduino IDE and later added to the arduino microcontroller component of the system which contains the set of instructions used by the arduino microcontroller for the system automation. The simulation was performed to ascertain the actual behaviour of system in real life situation and necessary modifications were made.

System architecture

The architecture of the proposed system is as shown in Fig 1 Our system constitutes of components shown in Fig 1. Microcontroller was connected to the GSM, temperature sensor, soil moisture sensor and ultrasonic sensor, SIM900 GSM module and an on-board USB charging port provides a convenient method for recharging an in-built battery in the system. LCD is used for continuous display of messages. GSM module is used to send a tank level notification to the farmer's mobile phone. Temperature sensor and soil moisture sensor are used to read the temperature of the field and soil moisture sensor to read the soil water content of the soil respectively. The power supply to the system was built with solar technology to help the system have steady power supply. An Arduino microcontroller unit is programmed for this purpose.

Flow diagram of the proposed system

The operational flow diagram is as shown in Fig 2.

Description of technologies/tools used

The description of those technologies and tools used are given below.

Microcontroller

In this project, we used Arduino Uno, a small single chip computer which can be programmed to perform calculations and control a production line and much more. The microcontroller controls the actions of other components attached to it. Fig 3 represents the microcontroller.

Global system for mobile communication

The GSM is a communication standard that is based on wireless technology. In our system, when the GSM module triggered by the microcontroller sends text message which contains the location and time of scene to the security agency. The diagram of the GSM module is shown in Fig 4.

Temperature sensor

DHT11 is humidity and temperature sensor depict in Fig 5 produces ranged advanced yield. DHT11 can port with any microcontroller like Arduino, Raspberry Pi, *etc*. and get sudden results.

Soil moisture sensor

The soil moisture sensor uses capacitance to measure the moisture content of soil by evaluating the dielectric permittivity of the soil, which is a part of the water content. Sensor is embedded into the soil to be tested and the volumetric water constituent of the soil is accounted for in percentage. The moisture sensor diagram is as shown in Fig 6.

Ultrasonic sensor

Ultrasonic sensor diagrammatically shown in Fig 7 is an electronic device that can measure the distance to a body or object by using sound waves. It calculates and measure distance by sending a sound wave at a precise repetition and timing for that sound wave to bounce back.

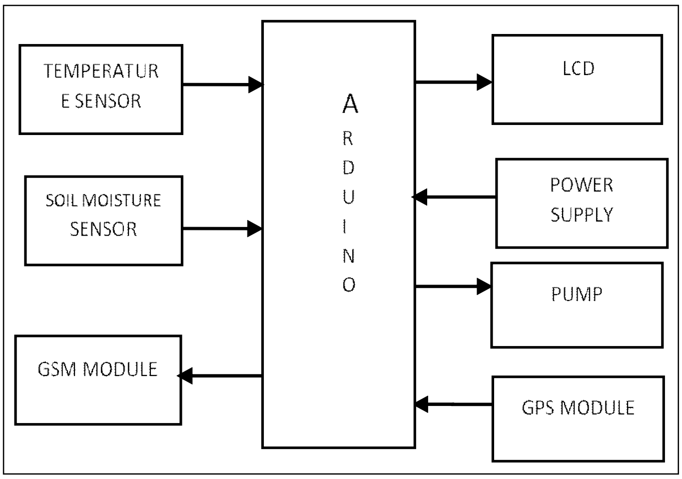

Fig 1: Block diagram of the proposed system.

LCD

LCD stands for liquid crystal display 20 × 4 (units). It can display 20 characters in a line and there are 4 rows of lines. The data is the ASCII representation of the character to be displayed on the LCD.

Global positioning system (GPS)

The location information of the object that is interfaced to the GPS is being tracked. GPS obtains the latitude and longitude information from the satellite and the form part of the message sent to the farmer via GSM. Fig 8 below is a diagram of GPS module.

RESULTS AND DISCUSSION

Simulation result

The screenshot in Fig 9 and Fig 10 show the simulation result of the proposed system.

Simulation result summary

The results of the simulation of the proposed system done in proteus were summarized in Table 1 and Table 2.

Implementation result

The proposed system was experimentally built to verify its functionalities. All the identified components of the system listed and explained in section 4 of this paper were gathered and appropriately connected as prototype as shown in Fig 11. Subsequently, the system was tested to verify the result.

The microcontroller is set to action and it triggers other peripherals interfaced to it through its control function. These other peripherals include Pump, GPS and GSM modules. When the soil moisture sensor and the temperature sensor capture temperature value and the soil moisture value of the soil respectively, the signals are sent to Arduino controller for decision making (Boby *et al*., 2019). The soil moisture threshold value and temperature threshold value were set

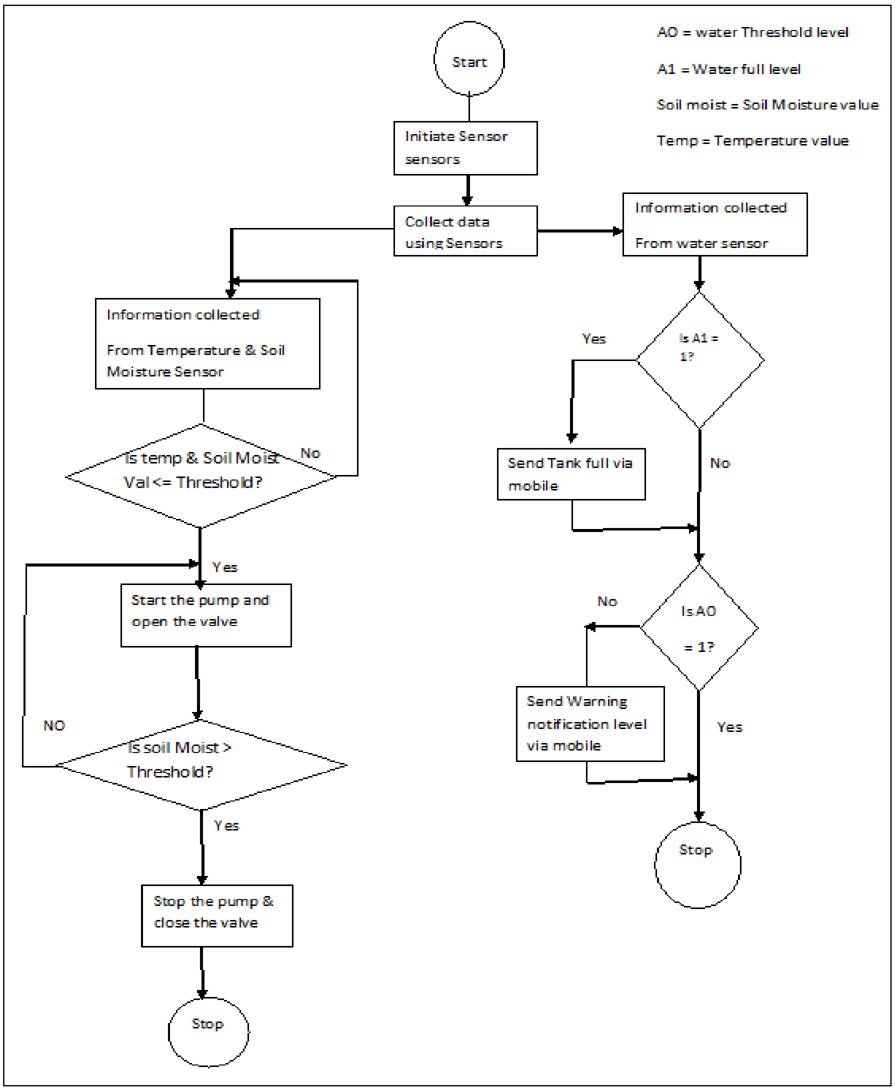

Fig 2: Operation flow of the proposed system.

to 300 and 25°C respectively. Based on the read values, the controller will switch ON or OFF the pump Priyadharsnee and Rathi (2017). When the soil moisture value is less than 300 and the temperature less than 25°C the controller will switch on the Pump for irrigation to take place as shown in Fig 12. If soil moisture value rises more than the threshold, the controller will switch off the pump without considering temperature value as shown in Fig 9. Controller also uses the ultrasonic sensor to capture the maximum and minimum water level of the tank denoted as A_1 and A_0. If ultrasonic sensor detect that A_1 is high, the controller will send a message to the farmer notifying him/her that the tank is full *via* GSM. If A_0 is detected to be low, the controller will send a warning message informing the farmer to place an order to refill the tank as shown in Fig 13. The sent message contains the location information of the tank to be refilled which was captured by the GPS component of the system. All the actions that were involved are depicted in Fig 2 above.

Table 1: Moisture and temperature sensor values and action taken.

Moisture sensor value	Temperature sensor value	Action taken
Below 300	Below 25°C	Pump turned on
Above 300	At any temperature value	Pump turned off

Table 2: Ultrasonic sensor values and action taken.

Ultrasonic sensor value	Tank's water status	Action taken
Above A1	Tank filled	Message sent
Below A0	Insufficient water	Message sent
Between A1 and A0	Sufficient water	Message not sent

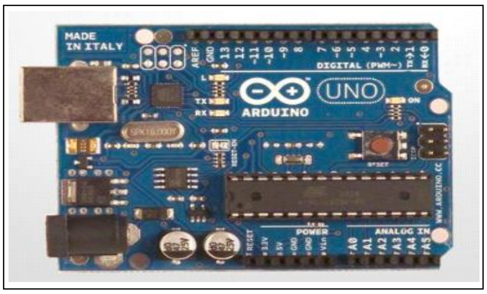

Fig 3: Arduino microcontroller.

Fig 4: GSM module.

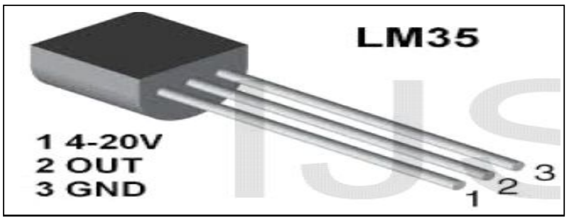

Fig 5: Temperature sensor.

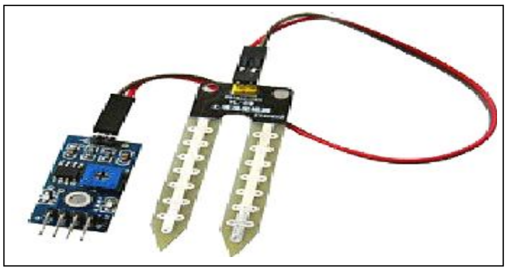

Fig 6: Moisture sensor.

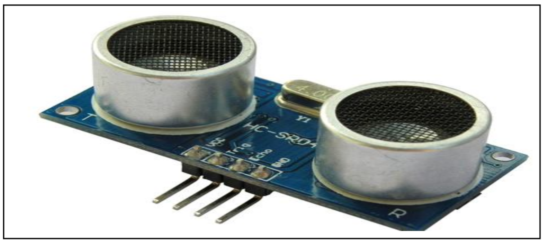

Fig 7: Ultrasonic sensor

Fig 8: GPS module.

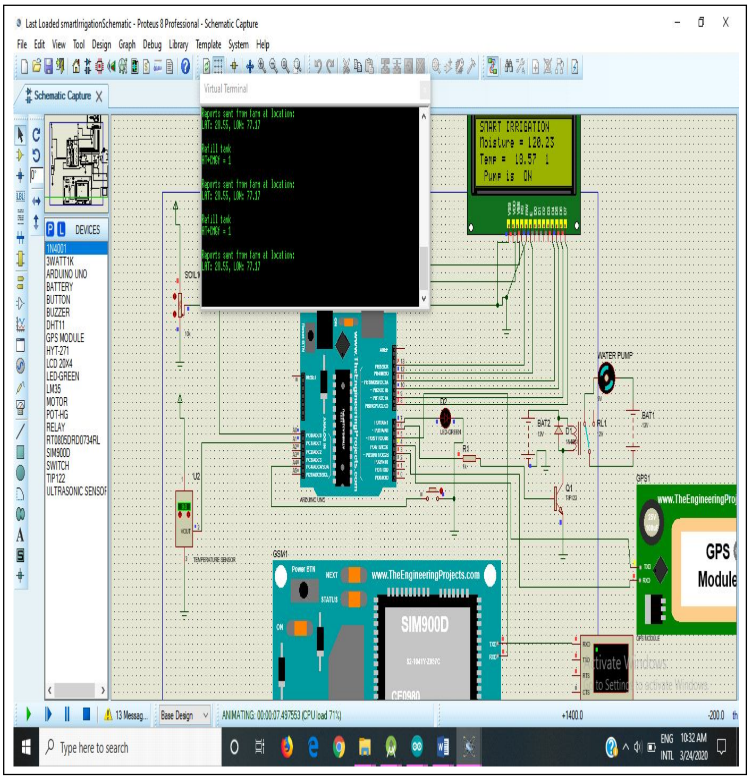

Fig 9: Proteus simulation showing when pump is ‘ON’.

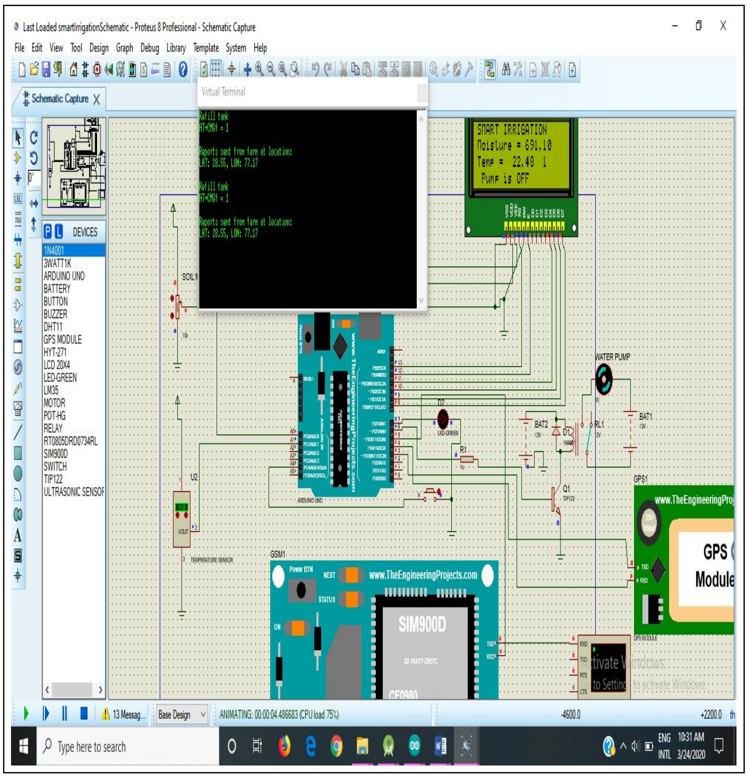

Fig 10: Proteus simulation showing when pump is ‘OFF’.

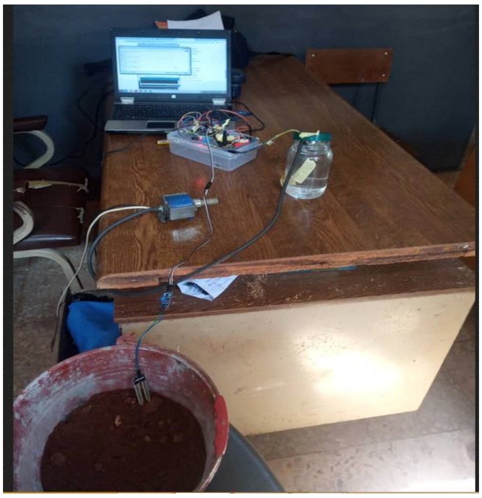

Fig 11: System implementation prototype.

Fig 12: Automatic watering by the smart system prototype.

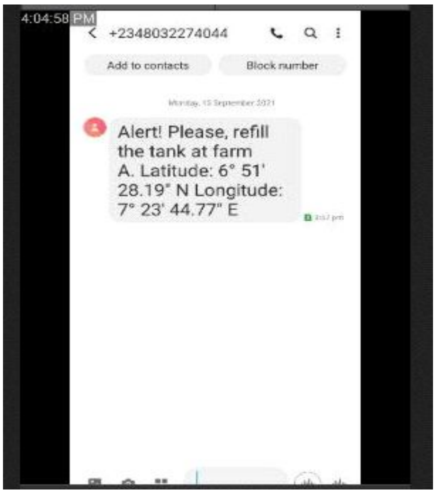

Fig 13: Message alert to refill tank.

CONCLUSION

The proposed system will help to minimize the cost of production, reduce the level of human involvement, guarantee water availability and conserve water for irrigation. The system setup includes moisture sensor for reading moisture level of the soil, ultrasonic sensor for reading the water level in the tank, pump for watering crops, GPS for tank's location detection, GSM for alerting the farmer and microcontroller for decision making. With this cost effective system, farming is smarter and crop production is significantly increased.

Conflict of interest: None.

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