Smart Agriculture and Food Storage System for Asia Continent: A Step Towards Food Security

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ABSTRACT

Asia is the largest and most populous continent of Earth with an overall population of 446.27 crores. Housing this population drives various challenges in different aspects, in which providing healthy and nutritious food to each and every individual is most challenging. Unfortunately, because of certain production issues, farmers are not getting the desired throughput, and in some critical cases, situations lead to suicide. On the other hand, proper storage and distribution of these harvests are other challenges. Various models and IoT (internet of things)-based approaches have been presented and are available for implementation, but a dedicated layout combining the digitization of all the essential steps, starting from preparation of soil for agriculture to the making food available for every needy person, is still missing. In the paper, various related models have been studied, and an integral model is presented where integration of IoT is carried out with agriculture and with the food storage and distribution system.

KEYWORDS

Farmer Suicide, IoT, Sensors, Smart Agriculture

1. INTRODUCTION

The alarming population of Asians country is not an only challenge in itself but the arrangements of their livelihood and to provide them with an adequate life style is a bigger challenge for the governments. Study shows (refer Figure 1 (left)) that the population of Asia pacific is expected to shoot by several Billions by 2050 (Max Roser n.d.). In all the other related essentials, proper food is most important and for that there is no any alternative except agriculture industry. Despite of various measures to increase the productivity and harvests, still there are an un-ignorable number of populations falling in undernourished category (refer Figure 1 (right)) (Max Roser n.d.). U.N. Secretary-General Ban Ki-moon has highlighted this issue in his address to world food security in Rome and stated that, “today, more than one billion people are hungry, and six million children die of hunger every year -- 17,000 every day. In 2050, the world will need to feed 2 billion more mouths -- 9.1 billion in all” (Joy Prakash Chowdhuri 2020).

This is not it, people are not only dying because of hunger, more than several thousands of farmers are ending their lives by own, every year, some being besieged by bad weather, some by

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falling into a debt-trap. This problem is mainly persisting in the South Asia; in a country like India almost 300,000 farmers have committed suicide in last 20 years. The suicide rate among Indian farmers was 47 percent higher than the national average. And the sad truth is, in India agriculture is the largest employment sector but its contribution in GDP was only 15.2% in 2019 (India's shocking farmer suicide epidemic, 2015).

Figure 1. (left) Population projection by UN, 2050 (right) Share of Undernourished people

Another associated problem is the wastage of food. Surprisingly, around 20% of the grain and 42% of the vegetable and fruits produced in Asia continent is wasted. This percentage appears very huge when there are people starving to death and farmers are committing suicide. This is a global concern, worldwide; 1.3 billion tonnes of food - enough to feed 3 billion people - is lost every year. The regional representative of Asia Mr. Konuma, has mentioned, “Food and Agriculture Organization has estimated, if the wastage could be reduced by just one fourth, enough food can be saved to feed around 870 million people across the globe. He further suggested that the production should be increased by 60% anticipating the further increase in the world population, which is expected to be 9 billion by 2050 (As millions go hungry, Asia battles food waste, 2013).

In the proposed work the integration of IOT is carried out with existing agriculture system. With the technology exploration now almost everything is becoming smart with the adoption of technologies and the result obtained is fabulous and have encouraged the research fraternity to excel in every horizon. IOT is an emerging technology that can provide excellent control and monitoring of any existing systems with the help of various sensors and interactive platforms. With the help of IOT and few other technologies such as cloud storage, smart GPS, web integration, the agriculture system can be changed to enhance the productivity with least efforts and without any enormous change in the existing infrastructure.

The organization of subsequent sections is according to the ideal format of a research paper. The second section is highlighting the need and motivation of the proposed work, in section three a short literature review is presented highlighting the recent contribution made by other potential researchers, in section four the existing model of agriculture is discussed along with their limitations, in the same section a brief about IOT is given so that reader can develop the required understanding of the context. Later in the same section some important sensors are also described that will be used of the integration of IOT with existing system. after all these background and motivation in section five the actual model is proposed describing all the procedure in details, it is also mentioned in the same section how this model will resolve all the limitations of existing model. In section six, paper is concluded combining all the results and prospective of the model. In the later part of the section the future scope of the model is also presented.

2. SCOPE AND CONTRIBUTION

In the proposed work a model is suggested, with the implementation of which a balance can be maintained between the production and consumption. As shown in Figure 2, the imbalance is mainly because of wastage of food, increasing number of population, and increasing number of suicide cases of farmers. In Figure 2 it is suggested that by incorporating IOT with production and storage of food this balance can be maintained. The advantages of maintaining this balance is twofold, it will not only help in feeding the needy, it may become a cause of relief of farmers and may stop the increasing suicide cases. There are various researches going on for this purpose, but the actual implementation of these at ground level needs to be ensured. In the proposed work we have suggested some IOT based model not only for smart agriculture but also for smart farmers and intelligent food storage system. An integral approach combining all these aspects can be revolutionary in the field of agriculture and can save millions of lives and food.

Few important sensors that are being used are soil type sensor, moisture and humidity sensor and pest sensor (Das R.K., et al 2019). Based on the problems faced at different stages of agriculture, appropriate application of these sensors is proposed. This will help in monitoring and controlling every stage separately with an eye of technology. A threshold is set at every step and the value obtained from the sensor is compared with the threshold value and necessary steps to be taken are suggested.

Figure 2. Representing inequality between production and consumption

3. LITERATURE SURVEY

Agriculture is a global issue that's why this topic has grabbed the attention from researchers across the globe. Few of them are listed here which has helped writers and guided for the proposed work. In (Muangprathub, Jirapond, et al, 2019) the authors have proposed a wireless sensor networks development for watering crops to optimize agriculture to design and develop the control system between node sensors in the field of crops and the data management via smartphone and web application. In (Brewster, Christopher, et al, 2017) the authors have outlines the challenges and constraints that an large-scale pilots (LSPs) deployment of IoT in the domain of agriculture must consider. Sectoral and technological challenges were described in order to identify a set of technological and agrifood requirements. An architecture based on a system of systems approach was briefly presented; the importance of addressing the interoperability challenges faced by this sector was highlighted. A description of the technologies and solutions involved in designing pilots for four agrifood domains (dairy, fruit, arable, meat and vegetable supply chain) was eventually provided. In reference (Ruan, Junhu, et al, 2019) the authors have addressed challenges faced in the large-scale

application of IoT systems in agriculture, such as huge investment in agriculture IoT systems and non-tech-savvy farmers. To identify these challenges, they have summarized the applications of IoT techniques in agriculture in four categories: controlled environment planting, open-field planting, livestock breeding, and aquaculture and aquaponics. The focus on implementing agriculture IoT systems was suggested to be expanded from the growth cycle to the agri-products life cycle. In reference (M. A. Ferrag et al, 2020) the authors has started by describing four-tier green IoT-based agriculture architecture and summarized the existing surveys that deal with smart agriculture. Then, they have also provided a classification of threat models against green IoT-based agriculture into five categories, including, attacks against privacy, authentication, and confidentiality, availability, and integrity properties. In (Banerjee, Susmita, et al, 2020) the authors have proposed an IoT enabled monitoring system to deploy in remote areas where the accessibility is very minimum for farmers with good storage facilities to reduce food losses and increase food safety. In (Ahmad, et al, 2020) the authors have designed and developed an IOT based monitoring system for smart agriculture. In the complete structure they have used microcontroller, GSM module, Bluetooth module, SD card module and other sensors. They have developed an application also to display all the data.

4. THE EXISTING MODEL OF AGRICULTURE AND INTEGRATION OF IOT

4.1 Existing Model

In the following section a brief about the existing agriculture process is discussed which covers all the essential steps of agriculture as represented in Figure 3. Along with discussing about all the steps in brief major drawback of these steps is also discussed which has helped in developing the layout of proposed system.

The first and important step is the preparation of soil for agriculture that must contain the desired minerals to properly grow the crops. And For a good yield, the crops should be developed and flourish properly and for that maintaining good quality of the soil is a must. The various factors that do affect the quality of soil are the excessive use of mechanical seedbed that causes soil disturbance. Furthermore, the soil gets disturbed because of continuously sowing same kind of crops. That affects the microorganism of soil and hinders the explorations of different depths of the soil layers for nutrients (Top 5 need-to-knows about Conservation Agriculture, 2014).

The second important step after preparation of soil is the sowing of seed that should be done according to the climate and season. A good quality of seeds is very important for good crops. That may be only possible if the seeds are stored and developed properly in a suitable and favorable environment. The effect of proper storage can be understood by the fact that only 1% increase in seed moisture content or 5°C increase in the temperature over and above the prescribed limit can reduce the lifespan up to half (Baker, N. 2005).

Once the seeds have been sowed proper care is required and manures and nutrients should be added with due measures. The soil contains various nutrients and manures but many of them removed and exported during the harvesting of crops. In order to maintain the required level of nutrients and manures, the removed ones must be replaced with synthetic manures, fertilizers, municipal wastes. The plant nutrients are generally categorized in macronutrients and micronutrients, based on the amount of nutrients required for the growth of soil. But regardless of these characterization a law was given by Liebig's known as "law of the minimum" for crop and states that the level of plant growth can be no greater than that allowed by the most limiting of all essential plant growth factor as shown in Figure 4 (Effects of Manure and Fertilizer on Soil Fertility and Soil Quality, MANITOBA state pdf available, n.a). That fact depicts that the amount of nutrients in soil should be maintained up to appropriate limit, if this goes down yields will reduce and if it goes up that will increase the probability of agronomic problems.

Figure 3. Existing Agriculture Process

With these technicalities and details it's very difficult for farmers especially in Asian continent where almost 30% farmers (Business Standard, 2019) are illiterate to work with these precision. That requires an intelligent crop monitoring system which can help these farmers without any additional labor cost and with little hands on training on the technology.

After all these efforts and time, once the crop is harvested yet another challenge that affects the yield, and already discussed is the long storage of grain in the godowns or at other relevant places. The reason behind this loss is the moisture, insects, rodent and old stock.

4.2. IOT

The term IOT is referred for a system of vehicles, physical gadgets, home apparatus, and various other things, connected with programming, hardware, actuators, sensors, and network to make these things capable to interact and share information. This facilitate the digitalization of the physical world and help in connecting with the computer system, that bring the proficiency enhancements, decreases human efforts, economic benefits etc. (Karim AB, et al, 2018). These advantages have been the reason of rapid growth of the IOT devices, there were 7 billion IOT devices in 2018 that has shoot to 26.66 billion In 2019 and it is expected to reach 31 billion by the end of 2020(Security Today, 2020). The international IOT market is expected to reach a value of USD 1256.1 billion by 2025(INTERNET OF THINGS (IOT) MARKET, 2020). The main reason of its popularity is that IOT make it possible to observe and controls the devices remotely. Figure 5 is representing the basic model of a 'Web of Things' based checking framework (Zhao S, et al, 2017).

Figure 4. Barrel illustration of Liebig's "Law of the Minimum" (Government of Saskatchewan, 2019)

The use of IOT in agriculture can help in resolving all the issues stated above, with the help of sensors and other related platforms. Agriculture, being the backbone of various economies and even provider of most important element of human life, is still existing with a lot of its traditional methods hence needs modernization, that open the various opportunities and scope to combine IOT with agriculture. This will certainly make the agriculture system more efficient and profitable (Muangprathub, et al 2019).

4.3. Sensors to be Used

In this section a brief description of important sensors is carried out. These sensors are represented in Figure 6 and are used in the proposed model with an integration of IOT and use to maintain the prescribed atmosphere for the production and storage of crops.

Figure 5. IOT Ecosystem

4.3.1. Temperature Sensor

Temperature is one of the most crucial factors that held responsible for the proper growth of crops, and is equally responsible for the proper storage in the godown. Any change in the temperature below or above threshold may result in suboptimal plan growth and damage of food grains in the storage. Various cultivars require different temperature for carrying out important plant processes like photosynthesis and growth at different stages (V. Otazú, 2010). Hence it can be understood that the proper monitoring of temperature is must that can be maintained by temperature sensors. It is a device comprising of resistance temperature detector or thermo-couple and measure the current temperature with the electrical signal. These sensors collect the data related to temperature and convert it into an understandable format for an observer of device.

4.3.2. Humidity Sensor

Humidity is another important factor for the proper development of the crop and a certain level is required for storing the grain in godown without any damage. Any imbalance in the humidity of the godown may rotten and damage the crop. That's why an adequate mean to measure the humid content of the godown will help the famers in maintaining the desired moisture in the godown. It was reported by Wang et al. that the moisture content of the air may be observed by a humidity sensor (C. Wang, et al, 2015). These humidity sensors comprise of sensing materials that may by ceramics, composites and polymer (S.D. Zor, et al 2016).

4.3.3. Light Intensity Sensor

The light intensity effects the growth of plants in an unparalleled way and it is equally important for the storage of grain in godown. Light sensors are an electronic device use to measure the presence or absence of light. With the help of these sensors the intensity of light may be measured and adjust accordingly. It is having various types and it helps in observing and controlling the intensity without any human intervention.

4.3.4. CO2 Sensor

Another important device is the CO2 sensor, which requires maintaining the appropriate level of carbon dioxide in the field and inside the godown for storage of grain and seed (H. Soffer et al 1988). A CO2 sensor is used for measuring the gas concentration of an environment. It was measured by Bihlmayr that these sensors are used to maintain demand based ventilation in an enclosed system (W. Bihlmayr, 2020). There are various types of CO2 sensors available, some are infrared based and some are chemical based.

4.3.5. Water Level Sensor

It is another important tool of IOT based agriculture and is responsible for maintaining the appropriate amount of water in the soil. These sensors doesn't only help the farmers in knowing the actual level of water in the soil, but it also helps in getting the information related to the level of nutrients available. These sensors are having capability to update the actors with the inappropriate water level, so that corrective actions may be taken accordingly.

4.3.6. EC and PH Sensor

Another factor responsible for the plant productivity is the EC and PH concentration of the nutrient and fertilizers given to the plants. An imbalance in these factors will affect the availability of the nutrients to plants (T. Asao, 2012). It's must to have a measure of these concentrations because an increase or decrease in it may change the compound from acidic to alkaline and the solubility of mineral varies according to the nature of compound (D. Borgognone, et al 2013), Thus to have a measure of these things it is important to have the sensors capable of measuring these parameters,

Figure 6. Sensors used in the proposed model (Imran Ali, et al 2018)

and these are known as EC and PH sensor. The data collected by these sensors must be observed throughout the progress of plants (S. P. Friedman, et al, 2005).

5. PROPOSED MODEL

Having understood about all the important aspects and limitations of the existing agriculture system and having a brief about the IOT and important sensors, in this section the proposed model is presented as shown in Figure 7. As it can be seen from Figure 7 that the proposed model is covering digitalization of all the essential steps of agriculture (Rathee, G, et al. 2019).

The first part of the model is representing the digitalization of soil preparation which is most important and primary part of agriculture. In section 4.1 the limitations of existing model has already been discussed and it was mentioned that the biggest challenge is the retention of the minerals and nutrients of soil after successive farming. In order to maintain the required property of soil it's required to have the proper measure of the composition of the soil that can be easily observed and monitored with the help of proposed model in which IOT based monitoring system is presented (Rathee, et al, 2019).

As shown in the first part of Figure 7, Raspberry Pi 3, sensors and microcontroller are connected in a particular way. All the sensors are connected through Raspberry pie-3. Under any unwanted circumstances the Raspberry pie senses the difference through sensors and sends the important signal to the monitoring system. For example, if the moisture or temperature of the field increases or decreases beyond the threshold limit the sensors will send command to the monitoring system to turn on or off motor or sprinkler. The alarm signal will be generated if any malfunction of system occurs. Furthermore the pets sensors is use to find the existence of harmful pets in the field and send the data to actors for taking necessary actions (Rathee, G, et al, 2019).

Once the soil is ready for sowing a good quality of seeds are required, that will laid the foundation of healthy and good crop and hence good yield. As already discussed in section 4.1 about the dependency of life span of seed on the storage conditions, in the proposed model an intelligent seeds storage system is proposed. In this the monitoring of ambiance of warehouse is to be done by humidity sensor, motion sensor, alarm and camera. These devices are connected to Raspberry Pi 3 through the

microcontroller. The signal is received by via these sensors and transferred to the microcontroller via raspberry pi 3. In case the humidity of the warehouse is increasing, that would be sense by the humidity sensor and that will automatically turn on dehumidifier to bring the humidity back to the threshold. And if, there are some pets in the warehouse, there motion will be sense by the motion sensor and that will switch on the rodent repellent accordingly. Even with the help of camera any unauthorized access may be monitored by the observers and necessary action may be taken.

Sowing a good quality of seeds can't grantee good yield, proper care and due measures must be taken to facilitate the growth of the crop. The various factors affecting the growth, had already been discussed in detail in section 4.1, in the proposed model an adequate solution is presented for resolving these issues. The main issue was of monitoring weather conditions, moistures, temperatures and soil characteristic throughout the growth of crop. For that soil moisture sensor, water level sensor, humidity and temperature sensor and PH & EC sensors are employed. These sensors collect the data from the field and surrounding environment and share it with the raspberry pie 3 via control system that takes the necessary actions accordingly. In case if the humidity or temperature got increased the controller will turn on the dehumidifier or coolant respectively, the type of soil will be decided by the PH & EC sensors, so that the appropriate quantity and type of nutrients and minerals may be added. If under any conditions the desire measure of these changes, the PH & EC sensors will sense that and the monitoring devices will work together to send a message to the actors to take necessary actions. Similarly appropriate water level is to be ensured by the water sensors. If the value of water is going beyond or above the desired level the sensors will sense this change and again the monitoring and controlling devices will work together to turn on/off motor. With the collective efforts of all the sensors and microcontrollers a suitable and appropriate atmosphere is created to grow and develop the crop unconditionally.

Another challenge discussed earlier was the storage of these grains in godown in an appropriate and suitable atmosphere so that we can save the millions of tons of grain that got spoiled in godown just because of improper storage. Various causes of these are already discussed in previous sections. In order to find appropriate solution motion sensor, humidity sensor and odor sensors are used along with microcontroller and raspberry pie 3. These sensors work along with other monitoring and control devices to ensure the adequate measures of each factor. Any change in any of the factors from the desired level is sense by appropriate sensors and intimated to the actors or controller. If the humidity is increased controller would be instructed to switch on the dehumidifier, if the existence of rodents are sense by the motion sensor the rodent repellent will be turned on, if some old stock is getting rotten because of any reason, the bad odor will be sense by the odor sensor and it will inform the concern person about that immediately so that corrective actions may be taken.

6. CONCLUSION

The proposed model is designed to digitalize the existing agriculture and seed/grain storage system so that the existing challenges may be addressed and we can make ourselves ready for the upcoming challenges. This model has effectively presented the methods by which not only production or yield would increase, but it has suggested genuine methods by following which the wastage of food and grain in warehouse may be avoided and a balance will be brought between the production and consumption. That will not only help to produce and store enough grain to feed the existing and upcoming population, but the increase yield and production will reduce the suicide rate of Asians farmers and their manual labour also. Thus in conclusion it may be said that the application of IOT in agriculture may bring tremendous changes in this essential field and can save millions of live, efforts and wealth. The increase yield of agriculture sector will also increase the GDP of country and will affect the life of people in various other ways also. The physical application of this model is not done because of limitation of resources, but all the sensors are proven to perform as describe while

Figure 7. Proposed Model

working with microcontroller and raspberry pie 3. One can perform the practical application based on the proposed model that will further increase the validity of the model.

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