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IoT based model of automated agricultural system in India

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***Abstract*— Agriculture has always been the backbone of human civilization and something which has helped us flourish as a species since the beginning. Along with this, agriculture and the associated sectors have always had a major contribution towards India's GDP (Gross Domestic Product). As of 2017, they serve about 17.3 percent of the total GDP of India. Agriculture has also been the largest source of livelihood, for decades, in over 58 percent of the rural households of the country. Over the years, agriculture has seen many technological advancements. Despite this, agricultural practices in India are still largely traditional and are dependent on human involvement in a major way. India has a net sown area of around 14 crore hectares out of which only 47 percent of the land is under irrigation and still majorly depends majorly on good monsoon to fulfil the water requirements. Irrigation aside, farmers also need to know a lot of other problems like not getting enough value for their crops, producing more crops than the demand for that crop and spending excess amount of money in transporting the crops to the market. All this can be avoided if we introduce the technology that has been theoretically present for quite some time but has not been implemented at the ground level, yet. We are talking about IoT (Internet of Things) which is basically a network of objects enabled by internet coupled with the web services that helps in interact with these objects. The IoT network would include three subsystems which would each aim to solve the three major problems stated above. The first would solve the supply-demand anomaly, the next would solve the irrigation problem but would also perform data acquisition using the different sensor nodes. The last subsystem would be aimed at designing such a model that would reduce the transportation costs of the farmers considerably by enabling a pool system wherein every farmer would benefit and reduce their expense.**

Keywords—Internet of things, Agriculture, Sensors, Expert system, Microcontroller

I. INTRODUCTION

We are living in 21st century, an era marked by rapid and unbounded growth in all spheres of life and in this time of technological growth one field which has kept up its pace is Internet of Things (IoT). The interconnection of different objects, sensors or daily life electronics item is broadly termed as Internet of Things. Overall IoT helps in connecting human and devices over internet through a widely distributed network. IoT is a package which comes with many capabilities such as it can sense and understand other objects through sensors or other factors, it can represent the same as it has been programmed for and also it enables devices to establish a basis of communication among devices present in IoT network.

As Internet of Things is growing tremendously, it is expected that by 2025 IoT will contain around 75 billion connected devices which is around 23 billion now. IoT is serving its novel values in many spheres of field such as healthcare management system, supply chain management system, home automation system and many more.

Agriculture has been the backbone of Indian economy since its inception as a concept. Like every sector it has also seen many technological advancements with developing science and technology, over the years. However, the practices opted for agriculture in India is still largely traditional. The approach to it is still human involvement oriented i.e. labour intensive rather than technology intensive. With a surge in IoT applications and sensor technologies that are making their way to every facet of the industry, agriculture should not be left behind. The vision behind implementation of IoT technology in agricultural domains like pre-plantation measures, irrigation and transportation after harvesting is to regulate agricultural system for better productivity.

In India, big problems due to which farmers have to bear agricultural losses that have been noticed during our ground level survey in agricultural field are that

- It's not just weak monsoon or unusual natural occurrences that cause loss to the farmers. Its sometime that before going for plantation farmers don't put emphasis on the market research and on the pattern of plantation being opted by other farmers that sometimes causes overproduction of a certain type of plantation in the market and so farmers don't get the proper price for their crop.
- Many times, crop rotation gets overlooked assuming that the very last time this land has yielded great so it will repeat itself and due to no proper monitoring of farmlands by experts, plantation goes on and turns disastrous some times.
- Unplanned irrigation or over-irrigation.
- Late harvesting or late reaching of crop to the market causes less of payback on crops. It mostly

happens due to unorganized transportation in agricultural sector.

There is a need to make an IoT based automated expert system for the monitoring of the agricultural field over above mentioned problems that has to be user-friendly to the extent of users which comprises of mostly illiterate population of India.

II. Literature Review

The first component of our project deals with the supply-demand side of the agricultural domain. Let us first start by defining what these terms mean. According to [1], Demand is basically the rate at which customers want to buy a product whereas Supply is defined as how much of a good or service is offered at each price. Demand also relates to the market price in such a way that when the market price is high, the demand becomes low. [1] Also states that in a real market, when the inventory is less than the inventory that is desired, the supply of the products as well as its price is increased to meet the demand. The part we are concerned with is the interaction between supply and demand. [1] Clearly shows us that when there is low Demand and the Supply is high, the price of a product goes down as too much of the product is available but is not desired.
How this translates to the agriculture domain is clearly demonstrated by the study in [2]. This study states that certain attributes of the agricultural product market set themselves different in compare to other markets and so ways to set agricultural product prices more unpredictable and strained than others. The general price level of an agricultural commodity alters the current or expected balance between supply and demand. Using the image below from [2], the following observations can be drawn (Fig 1):

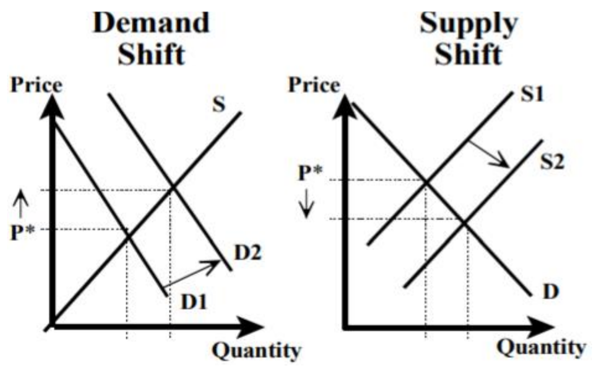

Fig. 1. Supply and Demand alteration with respect to Price Vs Quantity

Here in Fig.1 the outward shift in demand, meaning an increase in demand of a crop, would lead to raise the price as Demand moves to the right along the Supply curve. Likewise, an outward shift in supply, meaning an increase in supply of a crop, would guide to a lower price as Supply moves to the right along the Demand curve. At an equilibrium where the Demand meets the Supply, the price of the crop is the optimal price, that is, the actual price of the crop.
It is stated in [2] that differences between grain and oilseed prices throughout the world occur due to the difference in the local supply and demand conditions. It is also stated the price of a crop is high in densely populated regions, where the demand is high. The thing we aim to tackle is this very phenomenon of the interaction between supply demand using the predicted demand for a crop of a market. [2] shows us that the estimates of yield and probable production are published in each season for every crop. Using this very prediction and the system that we plan to deploy, we can help the farmers grow crops in such a way that the supply-demand equilibrium is maintained, and the farmers do not have to sell their crops at a lower price, which is the problem scenario that we aim to tackle.
Now focusing of irrigation part of the agricultural process, in [3] the author reflects how IOT is the way to go in order to ensure defining improvements in production, cost, time, efficiency, reliability and reduce human intervention in agriculture. [4] Presents a monitoring system which monitors soil properties using mesh of sensors, the system also comprises of a GPS unit, temperature and moisture sensor. It uses the sensor data along with certain other attributes like leaf wetness etc. in order to properly irrigate and monitor the crops. Just environmental data collection alone is not sufficient for increase in yield as in [5], sensor data validation is also required which can be done by a single central processing unit which will also take decision automatically according to that data. [6] Proposes IOT in the growing, harvesting, packaging and transportation phase of the agricultural production.
In addition to the system presented in [4] certain elements are added into the system presented in [7] like remotely controlled bots to take care of fertilizer spraying, weeding, animal scaring and keeping vigilance. It also proposes smart warehouse management. [8] Presents wireless sensor networks (WSN) and Precision Agriculture (PA) incorporated system to analyze weather and farm condition in order to utilize water as efficiently as possible while also increasing the crop yield of the farm. [9] Proposes a system to collect data from multiple points of a farm and show them to the farmer through a cloud enabled mobile platform wirelessly. In [10] the author presents an automated system which incorporates GPS for information like rain predictions, soil type, wine velocity etc. along with the sensors mentioned previously and merges them together with a cloud based wireless data storage which can also be viewed through a farmer friendly channel by the users and further data processing can be done in order to generate some valuable inference from the collected data. The author of [11] presents monitoring and knowledge base modules to provide information to the farmers and make profitable decisions on behalf of the farmer throughout the agricultural growth cycle. The author also shows current market prototypes of the similar modules. The authors of [12] presents system to minimize losses to diseases and pests by the means of preventive and proactive actions, with special attention on cotton crop. [13] Presents similar system but adds a camera module to capture images of crops periodically in order to notify the farmer of potential diseases or pests before it's too late to eradicate the problem.
The design of an IOT based agriculture platform named SmartFarmNet is presented in [14] which can assess crop development automatically by collecting relevant information and filtering obsolete noise data and processing it. SmartFarmNet is currently largest commercially deployed smart farm system worldwide which shows promising results

in the benefits of merging IOT in the agriculture domain. [15] Explores the potential of cloud and WSN in terms of their reliability, elasticity and availability in today's time in order to improve the ease and yield of agricultural cycle for ay crop. This paper focuses on the practicality of the automated system in order to help the farmer. In [16] the authors showcase the increased interest of merging IOT with agriculture in recent times. Although currently IOT in agriculture is in introduction state but the growth and interest are exponential. The open IOT platforms, interoperability and the improvements in the components is credited to the increase in interest. [17] Presents the idea of introducing IOT into agriculture not as a luxurious choice but as necessity in order to meet the ever-increasing food demand of humanity by increasing the yield. The paper also presents an automated system for the selective purpose of greenhouse agriculture using certain sensor data to monitor and automate decision making.

On the way of making an overall smart agricultural system, one of the crucial parts of this process is transportation of crops after harvesting. Ajiboye et al. [18] concludes that an amended and pre-measured transportation of harvested crops will reduce rotting off and wastage of harvested crops, empower the farmers, and will have constructive effect on their overall productivity and so income as it will be easier to move products to markets or agro-allied industry under a structured system of transportation.

The significance of transportation in agriculture is that it helps in creating market for agricultural produce, also helps in making ecosystem between economic and geographical regions. Tunde et al. [19] reveals that transportation of ready crops to the market at time with organized and planned harvesting brings improvement in productivity and helps in cost saving on agriculture for farmers as a community.

III. PROPOSED MODEL

A. Architecture of proposed model

Architecture of the proposed model is a multi-layered (k-layered) architecture which comprises of tiers in precedence order, which is connected through an IoT network as in fig 2. The whole model is tiered into farms that would comprise a geographical area entity let's say blocks. Different blocks would then comprise a city, the different cities would then comprise a commissionary and so on to state level. The basic and lowermost tier would comprise of network of sensors (SN) that would keep an eye on the condition of farmlands on ground level. Each individual microcontroller controlled device of SN that will be installed in farmlands will be provided with a unique id assigned to itself, with added information of area of fertile land that the device is covering, which would link the farm to its farmer through phone number, govt-id number etc., that will ensure an ordered data collection and is also necessary for the next steps of this proposed model All the collected data will be send to the cloud associated with the id of that particular local device and also shown to the farmer using very simple and easy front-end ensuring data access to the farmers as well through their cell phones. This data will also be accessible to the topper tiers and so to the experts present there.

All the other top k-1 tiers would be the administrative tiers that would help in balancing the crop requirement, monitoring and controlling the lower tiers of itself. The $(k\text{-}1)^{th}$ tier would be the closest observer of the conditions of the farmlands and local experts having proper farming knowledge would be employed here to help farmers in suggesting and monitoring the condition locally. This very tier would act as bridge between administrative or more look-out tiers and the local observer tier. All the above tiers would help in establishing a transparent and uniform farm market by balancing supply demand of crops and by providing organised framework for timely transportation of crops.

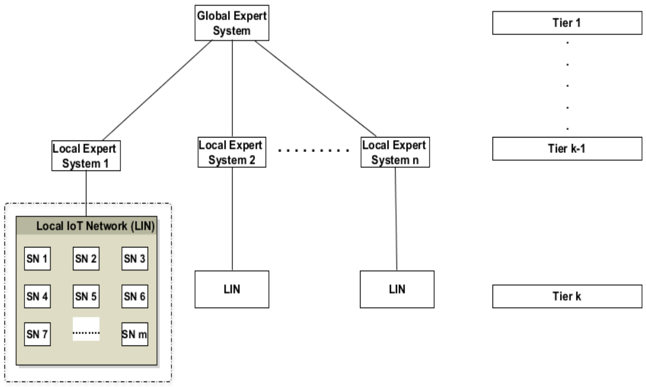

Fig. 2. Architecture of proposed model

This whole system is integrated with farm markets by providing an interface to marketers also that will help them to plan their fiscal transaction and to mark and target farmlands according to their interest of business. This whole architecture is not just restricted to farmlands only. It could easily be modified to pisciculture, poultry farming etc.

B. Supply-demand balance

As per the problem mentioned, we have planned to tackle the supply-demand problem that plagues the Indian Agricultural System and its farmers currently. For each farming seasons that comes along, based on previous years data, there can be an estimate drawn about how much demand there is for a crop at the markets in each level of our model. We would have the demand predictions for the different crops for the markets at each level, that is, let's say at the district, city/town and the state level. Assume that an area under the 2nd lowest tier of proposed IoT network is divided into farms in the following manner:

Farmland A	Farmland B
Farmland C	Farmland D

We have to decide the crops that would be grown for this area in the Kharif season of a year, say 2023. We would already have the data for the Kharif season plantations in these farmlands for the past years as the crop dataset (starting from the deployment of our model). Also, the sensors deployed in fields modulated in IoT devices is continuously collecting data using the different sensors like temperature, humidity and soil moisture. We would also have this as the climatic conditions dataset (averaged over the entire season for each season, each year) and the Crop Growth that resulted in that season as the outcome dataset for each of these farmlands.

Using the crop dataset as the class and the corresponding climatic conditions dataset as the raw data, we would use the weather forecast predictions for the entire season and employ the K-Nearest Neighbours (KNN) Algorithm to find out which top three crops is best suited for each of these farmlands according to local crop ecosystem. Keeping crop rotation in mind, which is very vital for the land, our system would then suggest the three crops that are best suited for each of these farmlands to the farmers of these lands. Assume Farmland A had grown Crop 1 previous year and this year, the KNN Algorithm suggests Crop 1, 2 and 3 for Farmland A, we would change the order to Crop 2, 3 and 1 keeping crop rotation in mind.

The KNN Algorithm works in such a way that using the Euclidean distance between the climatic conditions dataset and the prediction data, it would suggest the top three nearest classes (crops) which have the least distance in the Euclidean distance calculation above.

Now, the Farmer of Farmland A, as per our suggestion, would tell our system through his interface that he chooses to cultivate Crop 2 on his land. Using the outcome dataset, we would then predict approximately how much of Crop 2 would be cultivated on that Farmland. We already have the demand predictions for Crop 2 for the markets of this area (X), which we would then reduce by the prediction of cultivation of Crop 2 (Y). The remaining demand for Crop 2 for that area would then be X-Y. If the Farmland C also plans on cultivating crop 2, the remaining demand (X-Y) would then be used to subtract the prediction and finding a balance between supply-demand. If both Farmland A and C are opting for Crop 2, our system would decide based on an FCFS (First Come, First Served) basis.

Whenever the farmer opts to cultivate a crop in his land, we would display this supply and demand number to him using the X and Y mentioned previously and if the supply exceeds the demand, we would strongly advise the farmer not to cultivate that crop as that would result in everyone getting less value for their harvest. This we would do for all Farmlands A, B, C and D in this area and for all areas going up through all levels of our model.

Since our system is multi-tiered, divided into local area IoT networks (LAINs), and more of precedented big area network covering many LAINs, any increase or decrease in the demand/supply would be balanced in the other counterparts on the same level. Assume LAIN A had a Demand Z for Crop 3 but the supply in that district is W, where W>Z. So, the Demand for Crop 3 in LAIN B would then be reduced by the amount the supply exceeds the demand in district A, that is, W-Z. This way, the balance between Supply and Demand in the maintained and appropriate value for the harvest is achieved overall.

Of course, it goes without saying that all that our system does is suggest crops to the farmers. The final decision on which crop to cultivate rests on the shoulders of the farmers. If the farmer of Farmland A or all Farmers of the four Farmlands in the earlier example chose to cultivate crop A itself based on last season's success, all our system would do is advise strongly against it. We believe that deploying this model with this subsystem would help the farmers achieve optimal value for their harvest as the balance between supply and demand would be maintained.

C. Irrigation

One of the major tasks in front of any farmer in the growth cycle of any crop is that of providing accurate and timely irrigation to the produce, which means any farmer has to water the crop just the right amount and at the perfect time. More often than not, this becomes the biggest challenge in front of the farmer as little deviation from the apt amount of water can severely affect the yield, further, the timing of irrigation cycles is also very important in affecting the overall productivity. Today, in Indian conditions most of the irrigation decision is based on the guess of farmer instead of scientific knowledge, and involve manual labour in order to follow through. As in fig 3, our system plans to change that by deploying a device to each farm which will collect relevant information through sensors, analyze them and make automated irrigation decisions on behalf of the farmer. the collected data will also serve in providing solutions to problems other than irrigation like monitoring soil chemical composition, disease/insect monitoring and organize the farms and their information in order.

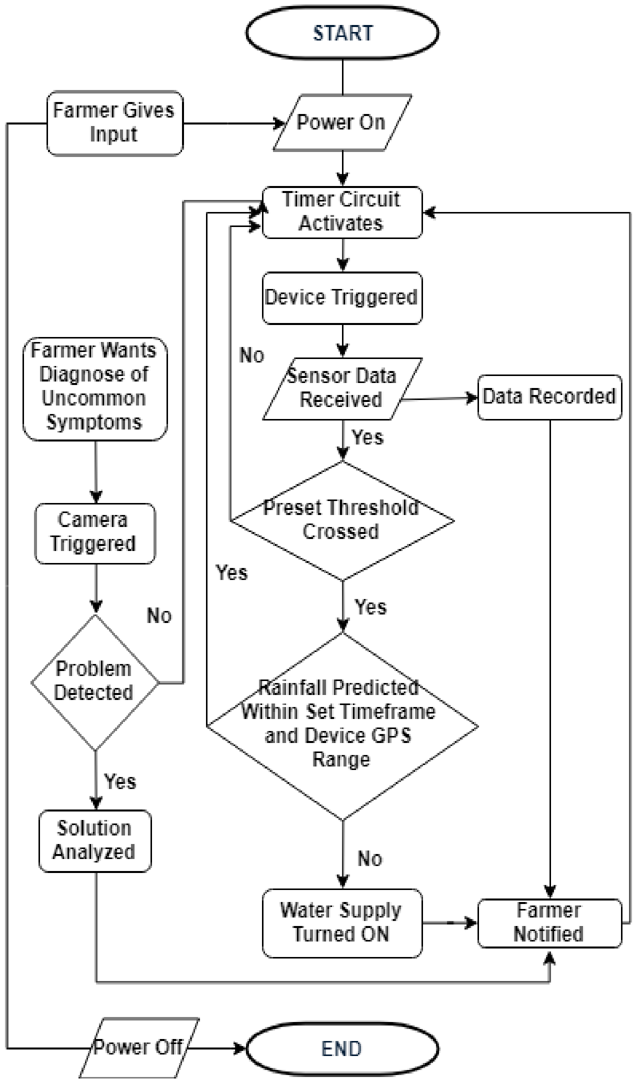

Fig. 3. Flowchart of working of micro controlled device installed in farmlands

Irrigation will be handled by a specially designed local device, which will consist of certain sensors like temperature sensor, soil moisture sensor, humidity sensor, light intensity sensor and a few chemical composition sensors. Apart from the sensors a low powered camera module to capture images, a GPS module, a GSM module and a microcontroller will also be present in this device. For powering the components solar energy is best suited so a solar panel along with a rechargeable battery will be featured to ensure both direct supply and a power supply buffer. The sensors will collect the relevant information which makes it possible to decide on environmental conditions of the farm. Thresholds for these conditions will be set based on the type of crop they are for, so whenever the threshold is crossed the system is made aware and can take appropriate measure to nullify the effect. The chemical composition sensors will measure the essential chemical nutrient's presence in the soil throughout the cycle of production, e.g. phosphorus composition during the paddy crop cycle etc. The GPS module makes it possible to incorporate the meteorological predictions into the irrigation decisions, i.e. if the system decides that the crops need water, it will check the meteorological predictions of rainfall in that area and if there is low or no possibility of rain within a pre-set threshold of timeframe then and only then it will use artificial irrigation. All this information will be conveyed to the microcontroller to process and to decide. The GSM module is to connect the local device to the cloud or the upper tier and thus the farmer, that will also help in establishing a communication medium with individual farmers through the phone. GSM module is best suited because of its low cost and high range and availability even in infrastructurally backward area. To power the whole device a solar cell will be incorporated in the device which will be connected to a rechargeable Li-ion battery serving as the buffer energy supply in case of unavailability of direct sunlight on foggy days or nights. There will also be timer circuit which only fire the sensors and the microcontroller a set number of times in a timeframe, as it saves energy and 24*7 sensor data is not required.

D. Insect infestation and disease diagnose

The camera module incorporated on the device will capture the images of plant and will be sent to very above tier where experts would analyze the image of plant putting the focus on coloring of leaves, curling of leaves etc. to diagnose few of the most common insect infestation problem, diseases etc. (if any) and then recommend most apt solution to deal with these problems. The camera module, like the sensors will also be triggered a set number of times in a timeframe as real-time data will only cause cluttering and won't generate any useful inference. The camera can also be fired manually through a switch on the device or remotely through the front-end by the farmer in case he requires special attention on some not-so-common symptoms.

E. Organised transportation of crops

The proposed organized transportation of crops is divided into three phases. In the first phase, as soon as farmer realize that his crop is up for harvesting he can flag his field that will get notified to fellow farmers and local expert system. In second phase of it, as the farmlands keep getting flagged for harvesting and so transportation of crop to market, Marketers being the part of the system could accumulate the knowledge of location of farmlands of their interest and could talk to farmers about the sell, make a deal remotely and so can decide upon the mode of transportation to collect crops from farmlands. Also, it would be convenient for the farmer's community to keep track of each other's ready-to-sale crops so they can arrange mode of transportation on their own. In the third phase of it, as per farmer's consent or ease, he can decide on where and whom to sell his crop. This whole process would help farmers to cut the transportation cost on crops by a good margin which will in a way turn into profit for them.

IV. Validity of Proposed Solution

Our proposed model and solution to the given problem is capital and infrastructural intensive but will break-even soon and will enable farmers to use resources efficiently. This whole deployment of network is going to be organised by big bodies like government or insurance company or by cumulative effort of both. It is going to be one-time investment in the direction of organised agriculture in India which will help in better monitoring of farm fields that will help in reducing the risk of crop failure due to non-natural hazard reasons and so will help farmers to make more money out of it. We have conducted a survey among 100 participants consisting of farmers and experts of this field to check the validation of the whole model that resulted in almost unanimous go-to-do for this model. As farmers in India are mostly illiterate so to make this model feasible counters have been taken on that part and almost all the trade-offs with respect to traditional or ongoing model of agriculture has been taken into consideration. If done on a cyclic basis to keep an account on capital investment, from the deployment part of view also it is pretty feasible.

V. Conclusion

In this paper, we have presented an IoT based automated expert agricultural system. The development of a system for smart agriculture can be greatly furthered from the knowledge of local condition's dynamics. For that, a comprehensive study and survey of micro elements have been performed and the information attained was then employed in the shaping of proposed model and solution.

This whole proposed system is developed considering all the aspects of the problem and each subsystem of this system complements each other towards attaining the same goal at the end which is making life easier for the farmers. In an ideal case scenario, our model will be deployed as a service provided to the farmers for the digitalization of the agricultural practices in India.

This whole system is designed to get the farmers a fair deal in the market and to make the losses and extra expenditure of everyone involved as minimal as possible.

VI. FUTURE WORK

The future work on this system should have emphasis on incorporating an intelligent monitoring system that will decide on taking actions on its own according to the provided condition, which will eventually lead to less human efforts for the actual monitoring. On way of doing this would be to incorporate Image Processing in our Insect Infestation subsystem using the images clicked by the camera module as input. This model could easily be modified to pisciculture, poultry farming etc.

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