Internet of Things(IoT) based smart agriculture

India is predominantly an agrarian economy. [1] Farming contributes about 16% of India's GDP and about 60% of the country's rural households are dependent on agriculture and its related industries. The current practices are based on guesswork and there is little emphasis on improving decisions using data. The question then is, how can we develop better agriculture practices, develop solutions for climate controlled agriculture, reduce resource usage, avoid post-harvest waste, reduce pesticide and fertilizer dependency and improve quality along the whole value chain? One of the most promising solutions to this problem is smart agriculture which modernizes the current traditional methods of agriculture. Hence the paper aims at making agriculture smarter using automation and IoT technologies. The highlighting features of this paper include smart GPS based remote controlled sensors and drones to perform tasks like surveillance, crop spraying, moisture sensing, leaf wetness sensing etc. Secondly it includes smart irrigation with smart control and intelligent decision making based on accurate real time field data using drones. Controlling of all these parameters will be through any remote smart device or computer connected to Internet and the operations will be performed by the interfacing sensors connected to a gateway through communication protocols such as Wi-Fi, LoRaWAN, ZigBee, BLE modules depending on usage.

Keywords- IoT, automation, Wi-Fi, technology, productivity

INTRODUCTION

[2] Over the past few decades, the manufacturing and services sectors have increasingly contributed to the growth of the Indian economy, while the agriculture sector's contribution has decreased from more than 50% of GDP in the 1950s to 16% in 2018-19 (at constant prices). Low productivity in the sector is the outcome of various structural challenges, including heavy dependence on rainwater for irrigation, small farm land holdings and lack of access to technology and real time information.

The demand for food in India is growing every year. However, supply is constrained by marginal productivity gains in a majority of crops due to erratic monsoon conditions, the shrinking amount of arable land, climate change effects, reduction of available labors in agricultural fields and supply chain inefficiencies that lead to wastage of crops.

Although India is the leading producer of multiple crops like wheat, rice, pulses, sugarcane and cotton; there is a potential to improve sector performance as it faces multiple challenges throughout its production cycle.

[3] In 2018, India contributed 21.75% to the world's pulses production, the highest for any one country, 21.65% to the rice production and 12.32% to the wheat production. According to agristatglance2018, it accounted for about 25% of the total quantity of cotton produced, besides being the second highest exporter of cotton for the past several years.

TYPICAL FARMING CYCLE

Farming Life Cycle: Steps a farmer performs and information needed at each step.

[4] Different stages of cultivation process include Crop Selection, Land Preparation, Seed Selection, Seed Sowing, Irrigation, Crop Growth and Sterlite Technologies Limited, April 2020 2 www.stl.tech Harvesting. Farmers need information at each step of cultivation process to increase the yield of crop productivity. Some of the information needed at each of these steps include (Fig. 1):

Crop Selection
- Market need and sale potential of the crop.
- Crop selection considering climate and quality of land.
- Comparative pricing of different crops.

Land Preparation
- Effects of any disease/pests from the previous cultivation and steps required to minimize this impact.
- Fertilizers needed to bring land to its normal fertility depending upon the previous crops and fertilizers used.

Seed Selection
- Price and quantity needed per hectare.
- Water requirement.
- Suitable to particular area and climate.

Seed Sowing
- Optimal weather condition at sowing time.
- Seed sowing depth.

Irrigation
- Amount of water given to the plants.
- Frequency of irrigation.
- Critical time for irrigation.

Crop Growth
- Comparison of crop growth rate, leaf size, crop colour etc. with expected growth for given conditions and input.
- Frequency, quantity and method of fertilization.
- Average growth rate of the crop in appropriate conditions.

Harvesting
- Proper time and method for harvesting.
- Proper crop storage.

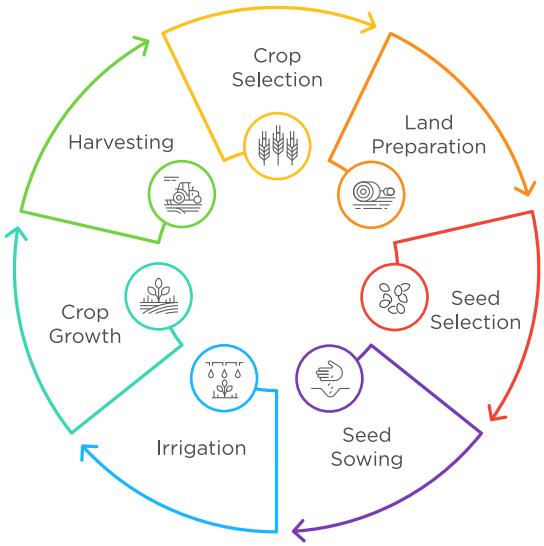


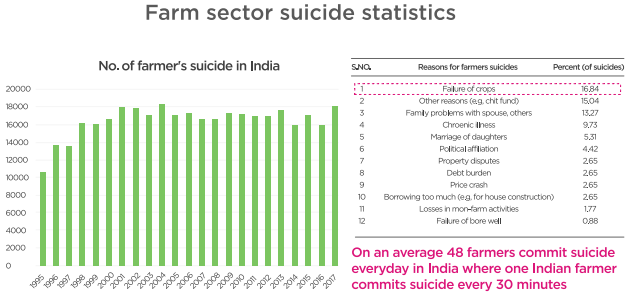
Figure 1: Stages of Cultivation

CHALLENGES

[3] However, the agricultural yield is found to be lower in the case of most crops, as compared to other top producing countries such as China, US, Europe and Brazil.

One of the banes of farming in India is the catastrophic crop failure due degrading soil quality, low mechanization rate compared with other countries like China, US and Brazil. India also faces the issue of underdeveloped supporting infrastructure; [10] only 45% of net sown area has access to irrigation facilities. Most of the farmers are not aware about their climate zones and suitable crops for their climate. This is degrading the environment by depleting the level of groundwater, degrading the soil quality and through salinization of soil which ultimately leads to the loss in agricultural sector in the long run.

According to National Crime Records Bureau an average of 48 farmers commit suicide every day in India where one farmer loses his life every 30 minutes(Fig.2) The main reason for the farmer's suicide is failure of crops. Therefore, by reducing the failure of crops and opting a decision based farming measure would reduce socio-economic problems such as farmers' suicides in the future of Indian agriculture.



Source: National Crime Records Bureau, 2015
Figure 2: Farm Sector Suicide Statistics

SMART FARMING TO THE RESCUE

The Information and Communication Technology based agriculture or smart agriculture is seen as a transforming force that will deeply impact the agricultural industry.

It specifies a transformation of the production infrastructures: connected farms, new production equipment, connected tractors and machines through sensors. It will enable an increased productivity, quality and environmental protection. It also creates modifications in the value chain and business models with more emphasis on knowledge gathering, analysis and exchange. Another important transformation in the agricultural production process is the rising role of automation that increases productivity by reducing the need for human taskforce.

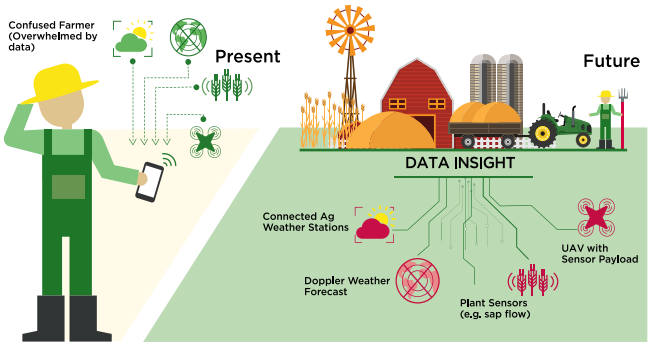


Figure 3: Centrality of data insight in future farming solutions

Therefore, the information needed by farmers to fulfil increasing need for optimum crop production with limited available resources is possible with better farming management. A better farming management is one which uses Information and Communication Technologies to increase the productivity in terms of ease in decision making, automatic response, remote management, health monitoring and sustainable use of resources.

TECHNICAL BENEFITS OF SMART AGRICULTURE

- **Water Conservation**
  Weather stations and soil sensors optimizes the use of water.
- **Lowered Operations Cost**
  Automating the processes related to cropping, treating the crops and harvesting can reduce the human error, non-renewable resources disruptive consumption and hence the overall cost.

- **Accurate Farm and Field Evaluation**
  Real time data captured by sensors allow the farmers to take adequate decisions hence track the production rates by field over time and hence can analytically predict the future crop yield. This would also help in estimating the value of the crop field.
- **Remote Monitoring**
  Decision can be made based on real time data and farmers can monitor multiple fields around multiple locations around the globe at the same time by a click on mobile's app.
- **Sustainable use of resources**
  Sensors laid in the fields and the weather station take real time data, helping the farmers to take decision analytically which in turn favors in the sustainable use of earth's footprint.
- **Real Time Data and Production Insights**
  Farmers can visualize the production rate of crops depending on the data generated by sensors for soil moisture level, amount of water needed in the farms, sunlight intensity, intensity of wind and many more.
- **Solution to stubble burning**
  There is a no. of different ways through which we can control air pollution, where instead of burning stubble it can be used for cattle feed, compost manure, roofing in rural areas, biomass energy, packing materials, fuel, paper etc.
- **Shift from "Farming to maximize production" to "Farming to maximize productivity"**
  Different Internet of Things would help the farmers by providing real time insight, process automation and hence take analytical decision based on the data provided by sensors. This would in turn help in maximizing the productivity and also protecting the earth's footprint; thereby increasing profit.

SMART FARMING ARCHITECTURE

Different layers involved in smart farming are (Fig. 4)

- **Sensor Layer:** It includes soil scanning, water, light, humidity, temperature management.
- **Data Communication Layer:** It includes accessing and transmitting data through a no. of access technologies like Lora WAN, cellular network, ZigBee etc.
- **Data Storage Layer:** This layer is used for data storage and analysing. It underlies the decision making and prediction processes.
- **Application Layer:** This layer includes the end user where they can monitor the field remotely through dedicated apps and services.

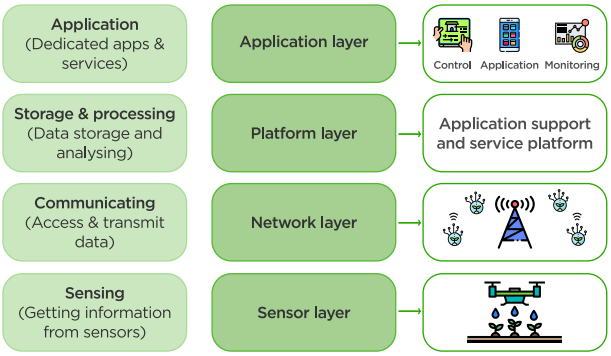


Figure 4: Smart Farming Architecture

Sensor Layer

This layer consists of sensors and physical devices. The layer identifies and collects the data and specific information generated by sensors and physical devices. The data gathered is passed to the network layer. In essence, the sensor layer bridges the gap between the physical world and the digital world.

[5] Data is the fundamental building block, whether it comes from water level detector, soil sample, imaging through drones or other sensors (Fig. 5). Data points collected can let us know about the variability in the field and on-time correction that would be required to produce crops efficiently. The layout of the sensors laid in the field depends on the type of data that would be required for proper monitoring of the field. Requisite choices have to be made as to

- Where the sensors and gateway are located?
- How many sensors are needed at the site?
- What is the payload size of the data packets?
- Whether a power supply is needed?
- How frequently data is collected?

Agriculture sensors and probes

- Weather station
- Rain gauge
- Wind speed and wind direction
- Temperature and humidity
- Electric fence monitor
- Leaf wetness sensor
- Soil moisture probes
- Soil moisture probes
- Tilt float switch
- Industrial pressure sensor
- Water level pressure sensor
- Flow rate sensor
- Air temperature & humidity probe
- Compass + Inclinometer
- Temperature probe

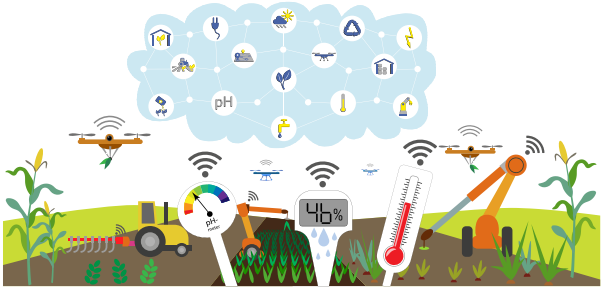


Figure 5: Agricultural Sensors and Probes

Along with the above mentioned sensors, agricultural drone which is a physical device would help in surveying and spraying few input materials (pesticides, seeds) to the field. There is a growing urge to meet the needs of increasing food demands and improving the water usage planning in farming to protect the earth's footprints. Agricultural drones are the most accurate solution for these problems (Fig. 6). Among all the technological advancements in the field of smart farming, agricultural drones seem to be one of the most promising solutions. They have multispectral imaging sensors for analysing the crop patterns, real-time monitoring of livestock, irrigation monitoring and management. The drone technology is said to have market growth in various spectrums of the world.

Agricultural Drones

Uses:

- Soil and field analysis
- Seed planting
- Crop spraying & spot spraying
- Crop mapping & surveying
- Irrigation monitoring & management
- Real-time livestock monitoring

Figure 6: Use-cases of agricultural drones

Network Layer

The data sensed and gathered by the sensors are connected to a gateway through communication protocols. Certain farming applications require the need of long battery life devices working on low data rate. Communication methods can be mobile wireless access networks, Lora, ZigBee, 6LoPWAN (IPv6 over Low Power Wireless Personal Area Networks) etc. depending on the usage. The network layer provides the functionality for network connectivity and transport capabilities. This layer is also known as "transport layer". This layer securely transmits the data gathered from sensors to the platform layer.

Platform Layer

The agricultural servers or cloud services are connected through gateways for data processing and storage. All the sensor's data relayed by IoT gateways is stored on cloud hosted servers which enables creation of dashboards for decision makers to monitor and thereby take proactive data driven decisions.

Application Layer

Application Layer is responsible for the management of all IoT systems, services and applications within the domain. This layer is connected through the internet via short range communication protocols and actively analyses the data through sensors reporting via LPWAN/LoRa/ ZigBee/low power radio technology. It analyses the data sensed by sensors to take accurate decision, hence converting "precision farming" to "perfection farming".

ECOSYSTEM FOR SMART FARMING SOLUTIONS

Agriculture is undergoing an evolution- [11] technology is becoming an indispensable part of every commercial farm. New smart agriculture companies are developing that help farmers to maximize yields by controlling every variable of crop farming such as field monitoring, soil sensing, water monitoring etc. though automation. Companies like Pycno, Arable helps the farmers to manage weather risk and crop health by delivering real-time and actionable insights from the crop fields. Farm(x), Phytech, Hydropoints are some of the irrigation management companies which are data-driven. A number of agricultural drone manufacturing companies like Skycatch, XAG, AgEagle would help the current landscape by mapping, surveying and spraying the crops. More about smart agriculture landscape map can be tracked using www.betterfoodventures.com [12]

The solutions provided by the OEMs offers almost complete details in all the spectrums of agriculture. It will help to provide solution and insights of all the crops in the fields which would increase the quantity and quality of agricultural products. Since agriculture is the backbone of Indian economy and the industry currently needs more support than any other. Can technology and data driven farming be the solution?

SMART FARMING MARKET

Global Smart Farming Market

Smart farming is gaining immense popularity among farmers due to the growing need of optimum crop production with limited available resources which needs to be used sustainably.

Further, the changing weather patterns due to increasing global warming have impelled the adoption of advanced farming technologies to enhance farm productivity and crop yield. The smart farming has the potential to transform the agricultural sector, making the traditional farming activity more efficient and predictable.

According to a research conducted by MarketsandMarkets, increasing global food demand, extended profitability, crop yield, and crop health monitoring for higher yield production are the major factors fuelling the growth of the smart farming market. Also, government initiatives in many countries are helping farmers to use optimized agricultural and technological tools to improve their production levels.

[6] The smart farming market is expected to grow from USD 5.1 billion in 2018 to USD 9.5 billion by 2023, at a CAGR of 13.4% globally (Fig. 8). The major factors driving the growth of smart farming market includes

- Increasing farm mechanization in developing countries.
- Rising labour cost owing to shortage of skilled labour.
- Increasing burden on the global food supply owing to increasing population.
- Substantial cost savings associated with smart farming techniques.
- Government initiatives to adopt modern agricultural techniques.

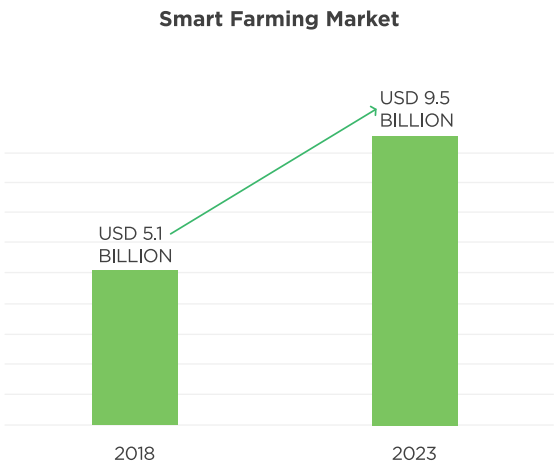


Figure 8: Global trend for smart agriculture

India vs China Market

[7] The area harvested in India in 2017 in terms of wheat is 30.6 million hectares with a productivity of 98.51 million tonnes whereas the area harvested in China in 2017 is 24.51 million hectares with the productivity of 134.34 million tonnes (Fig. 9). The proportionality is same in case of rice(paddy), maize and soybean. Through this data it is clearly evident that the productivity in China with respect to area harvested is more in comparison to India. [8] China invests significantly more in agricultural research and development compared to India to produce high-yield and quicker-growing crop varieties. According to the "Wall Street Journal", better irrigation and more intensive cultivation of the land by double or even triple cropping, are the primary reasons for China's superior yields.

Through the incorporation of smart farming technologies, we can take precise decisions, monitor our crops remotely and hence can improve the Indian agricultural landscape.

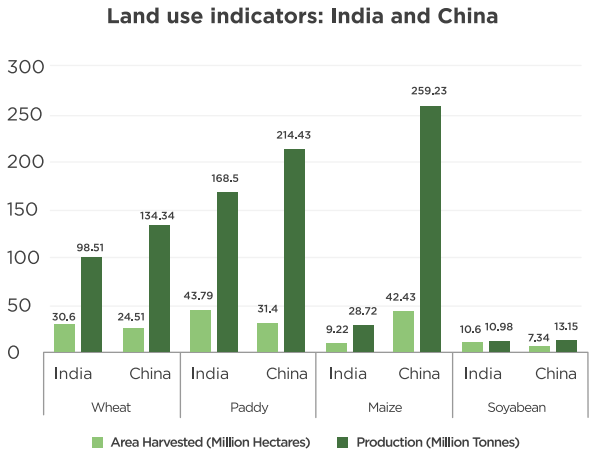


Figure 9: India-China yield comparison

CONCLUSION

The private sector can play an important role in redefining Indian Agriculture. [9] Indian Economy is predicted to reach 5 trillion- dollar by 2024 where the contribution in agricultural sector is estimated to be 20% or 4% increase is needed in agricultural sector to meet the demand of 5 trillion-dollar economy (Fig. 10). Through improvement in productivity in terms of yield and quality, Indian agrarian market can meet the requisite. The offering provided by smart agriculture in terms of irrigation management, precision farming, crop and livestock monitoring is spawning new business opportunities for private and government sectors.

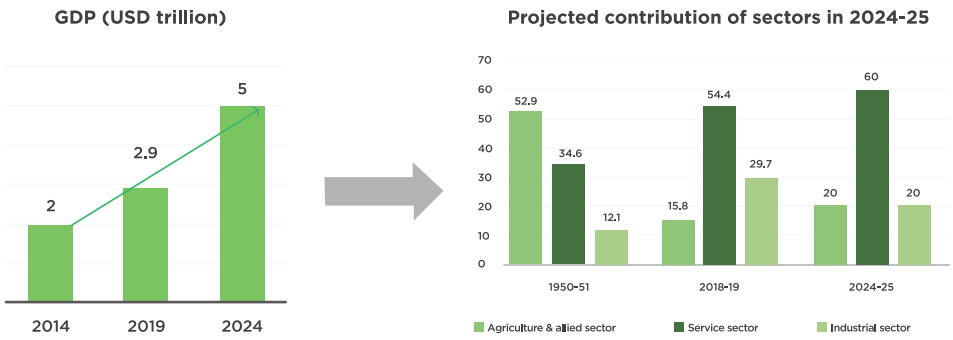


Figure 10: Estimated Indian Market Opportunity

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