Farm to Fork: IOT for Food Supply Chain

Shalini Vermani

Abstract: ***Globally, population is growing and at the same time our natural resources are shrinking. Most nations are facing challenge to feed their population in 2050. To feed growing population with stressed natural resources, there is a need to produce more with less. To achieve the target of zero hunger in 2050, it is not only required to produce more but also to reduce waste-age during storage and transportation. This paper discusses the use of Internet of Things in Food Supply Chain to fulfils future demand.***

Keywords: Drone, Farming, IoT, Supply Chain

I. INTRODUCTION

World population in 7.5 billion and according to Food and Agriculture Organization (FAO) of United Nations, world population will increase by another 2 billion and will reach 9.6 billion in 2050. In any economy agriculture plays crucial role and to feed the projected population of 2050, we need to boost food production by 70% (FAO, 2009). Challenge is not only to boost food production but also to protect food loss. Grains, vegetables, fruits and dairy products are vulnerable to temperature and other environmental conditions as they travel from farm to warehouse to retailors. In a scenario where one out of every eight people are suffering from hunger, 30% of the food is lost or wasted. Food loss is the loss of the food between production and distribution which is mainly due to improper storage or break in cold chain. This is not just the loss of food but also the wastage of resources like land, water, fertilizers and human labour etc. It also impacts the environment as food lost or wasted is accounted for 4.4 giga tonnes of green-house gas emissions. To provide nutritious and affordable food to 9 billion people is a big challenge.

According to World Health Organization (WHO), one in every ten people fall ill and four lakhs twenty thousand die every year because of contaminated food (WHO, 2019). One out of every nine persons in the world is malnutrition (FAO, 2019). According to the year 2019 report of FAO on food and nutrition, percentage of malnutrition population in the word is shown in Table I.

Table I: Percentage of Malnutrition Population

World	2005	2010	2015	2016	2017	2018
Africa	21.2	19.1	18.3	19.2	19.8	19.9
Asia	17.4	13.6	11.7	11.5	11.4	11.3
Central America	8.4	7.2	6.3	6.1	6.1	6.1
South America	7.9	5.3	4.9	5.3	5.5	5.5
North America & Europe	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5

Source: (FAO 2019)

Maximum percentage of malnutrition people are in Africa followed by Asia. In Africa and South America, there was a decline in the percentage of malnutrition people from 2005 to 2015 but after that there is slight increase in both the regions.

Food supply chain is from farm to retailors or from production to consumption. It crosses multiple national borders. WHO is working closely with FAO on food supply chain to ensure food safety. In a world of limited resources, a big challenge that each nation is facing is to feed its people in 2050. There are various challenges in achieving the agriculture target of 2050:

- Stressed water resources
- Unavailability of cultivated land
- Change in rain patterns
- Increase in temperature
- Rise in sea level
- Disturbance in eco system

All will have impact on every level of food production, livestock and fisheries.

There is a need for significant transformation in agriculture and supply chain to meet the challenges of food scarcity and climate change. Use of technology can bring paradigm shift in how we see farming and supply chain today. There is a need to evolve mechanism to link front-end activities of food supply chain like wholesaler, logistics, retailing etc with the back-end activities of food production. Food supply chain with IoT is the need of the hour and is known as **smart food supply chain**. IoT in food supply chain can be used for more production and quality of food and will avoid food loss in warehouse and transportation.

This paper discusses the need and effective utilization of Internet of Things (IoT) to fuel different sectors of farming and supply chain to feed the world population in 2050. This upcoming technology will increase the crop productivity and reduce food loss or waste.

II. RELATED WORK

It is observed that 9.2 percent of the world population (or slightly more than 700 million people) were exposed to severe levels of food insecurity in 2018(FAO, 2019). The applications of technology in the field of agriculture are used to improve crop yields or quality and to reduce costs. Precision agriculture assists the farmers in making better and well informed decisions (Fang et al., 2014; Kodali et al., 2014). Many researchers have focused on smart systems for monitoring and controlling agricultural parameters by enhancing productivity and efficiency. Current use of smart agricultural systems relates to collecting data on environmental parameters such as temperature, humidity, soil moisture and pH (Sureephong, Wiangnak and Wicha, 2017).

Revised Manuscript Received on October 05, 2019.

Dr. Shalini Vermani, Department of Operations Management and Information Technology, Apeejay School of Management, New Delhi, India. shaliniduggal06@gmail.com

Water is essential for agricultural production and food security. Yet, our freshwater resources are dwindling at an alarming rate. Water is often used inefficiently in the food value chain. FAO is working with countries to ensure water use in agriculture is made more efficient, productive, equitable and environmentally friendly. (FAO, March 2019). Emergent technologies, such as the IoT, Cloud Computing, Robotics, and Artificial Intelligence (AI), have the potential to change farming beyond recognition (Wolfert et al., 2017). IoT in agriculture and farming focus is on automating all the aspects of farming and agricultural methods to make the process more efficient and effective (Zhao, Lin, Han, Xu and Hou, 2017). With the combination of both advanced technologies in hardware and software, IoT can track and count all relevant aspects of production which can reduce the waste, loss and cost (Ezhilazhahi and Bhuvaneswari, 2017).

Less food and food waste would lead to more efficient land use and better water resource management with positive impacts on climate change and livelihoods. Reducing food loss and waste is critical to creating a Zero Hunger world and reaching the world's Sustainable Development Goals (FAO).

III. FOOD SUPPLY CHAIN IN INDIA

Agriculture is supporting the livelihood of large population of India and so is considered as the backbone of India. There is rise in demand of food grains but farmland and water resources are stressed, Acute dependency of agriculture is on rainfall. In addition to that there is unavailability of labours for agriculture as people are moving from rural to urban areas. There is decline of 25 million farmers from 2011 to 2015.Indian crop yield is significantly lower than the Asian average (FICCI, 2018). To meet the projected food demand of 2050, India will have to increase the crop yields.

Due to rising population, demand for food grains and livestock is continuously increasing, Demand of food in 2000 and the projected demand in 2030 are shown in Table II.

Table II: Food Demand

Demand in Million Tonnes		
	2000	**2030**
Pulses	14	30
Cereals	33	102
Wheat	64	95
Rice	81	156
Food Grain	192	355

Source: FICCI(2018)

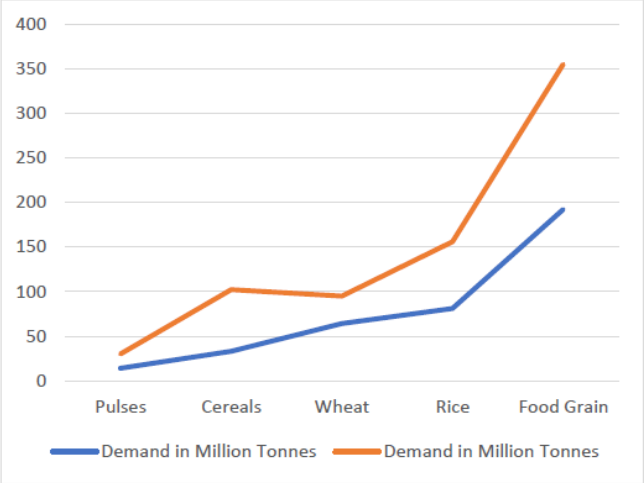

Fig 1: Food Demand

Food supply chain of India is inefficient which leads to large quantity of food loss. Approximately, 18% to 25% of food loss in India happens during supply chain i.e. between the field and consumer. 11% of global agriculture products are produced in India and at the same time India has one of the world's largest malnutrition population.

As far as smart farming in India is concerned, Microsoft is working with 175 farmers in Andhra Pradesh as a result of which there is an increase of 30% crop yield (per ha).

IV. CHALLENGES IN FEEDING WORLD POPULATION IN 2050

Globally, farmland and water resources are stressed. In most nations, there is acute dependency of agriculture on rainwater. Agriculture commodities are perishable and need different environmental conditions for handling but supply chains are inefficient. Few major challenges to feed the population of 2050 are:

Unavailability of Man Power: One of the main challenges is unavailability of manpower for agriculture. Globally, every second two persons are moving from rural to urban area, So, by 2050 only one third population will live in rural area.

Climate Change: Change in climatic conditions is affecting agriculture through heat waves, variable rainfall, droughts, rise in level of carbon dioxide and floods. According to a study on global warming states that by 2080 world's agriculture production will decline by 3% to 16% and it would be 17% to 28% in Africa.

Land Degradation: Availability of cultivated land is decreasing globally. Main causes of land degradation are deforestation and overgrazing of animals by which the top layer of soil washed away with rain.

Food Loss and Wastage: It is estimated that in developing countries 795 million people go hungry and approximately one third of the food produced is lost during production and transportation. Approximately 50% of food lost or wasted in Africa. Food wastage during production has carbon footprint of 4.4 Gt CO_2 equivalent which is harmful for the environment.

V. IOT FOR FOOD SUPPLY CHAIN

Farming and food industry are going to see digital revolution soon. This revolution will increase crop production and strengthen food safety throughout the supply chain. IoT promise to solve lots of issues related to agriculture, food storage and transportation.

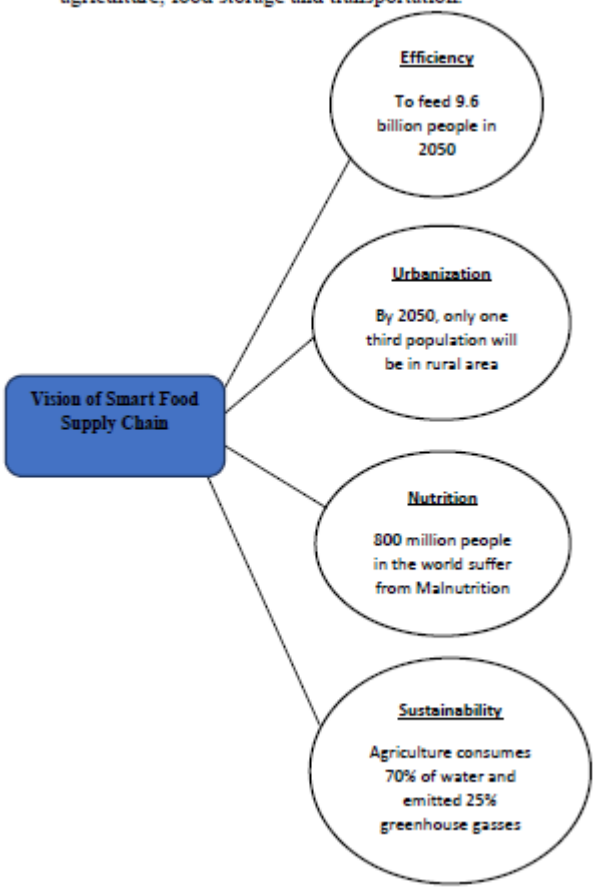

Fig. 2: Vision: Smart Food Supply Chain

VI. SMART FARMING

Smart farming includes integration of IoT with farming to improve crop yield and production efficiency and also reduces the usage of fertilizers, pesticides and water. With IoT, farmers can get better control over livestock and fields. Farmers can get the real time information of crop health, soil quality and weather conditions and also can take corrective measures from distance. Farmers are able to foresee the output of their crops and so can timely plan for better crop distribution to avoid any unsold product. In smart farming, crops, fields and livestock themselves send their information to the farmers. In this way, farmers can remotely collect the data from all the fields and herds consistently. Smart farming improves the efficiency and enables farmers to increase productivity with optimal utilization of resources and also reduces carbon emissions.

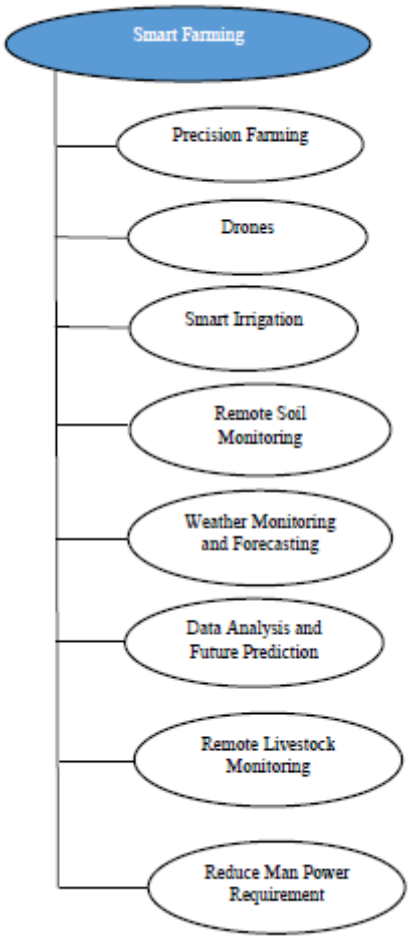

Fig. 3: Factors included in Smart Farming

A. Precision Farming

Precision farming is the application of information and communication technology in agriculture to identify, analyse and manage variability within fields. It focuses on improving the quality and quantity of yield using precise amount of water, fertilizers and pesticides. Precision farming is a new concept designed to identify the specific condition of every part of the field and to take corrective actions on right time and right way to provide better yields in more energy efficient way. Wider applications of precision technology will improve productivity, reduce production cost and conserve resources.

B. Drones

Drones in agriculture represent a new way to collect information about crops in a field. Drones in agriculture can be used for field analysis, crop spraying and crop yield management. An important benefit of drones is that they are affordable and can be deployed easily.

High precision cameras are used in drones which can be used for real time monitoring of crops and fields. The cameras in drones collect precision field images to identify the area of fields that require water or has stressed crops that need remedy. High precision cameras in drones could detect the disease in crops before it is visible to human eyes. Due to early detection of disease, it reduces crop loss and also the requirement of pesticides. By using IoT, drones can be connected to farmer's mobile and can send him the alert in case of identification of any disease or unusual condition. So, farmer can remotely

monitor his crops and need not be present in the farm. It also saves significant amount of time of the farmer.

C. Smart Irrigation

Climate smart irrigation is the need of the hour. Today, water resources are stressed globally and 70% of fresh water is consumed for irrigation. It is expected that by 2080, demand for irrigation will increase from 5% to 20% globally (Focus, 2017). With IoT, irrigation is managed more accurately and saves the overall consumption of water.

In smart irrigation, sensors are used in the soil to identify the moisture level of the soil. With IoT, sensors inform the farmer about how much minimum level of irrigation is required for the crop. Optimal irrigation reduces water wastage and also reduces the stress level of crops.

With sensors, machines analyse the historical weather patterns, soil quality and recommend the farmers the kind of crop to be grown and when and how much irrigation is required for that particular crop in a particular weather condition. This automation helps for better yields and also to conserve the water.

Drones for Smart Irrigation

Drones can also be used to avoid the wastage of water in irrigation. Drones with special monitoring equipment can be used to monitor the field and to identify the area facing hydric stress, so that irrigation can be done to that specific area and avoid the wastage of water.

With smart irrigation farmers are able to control the irrigation from remote location using mobile app.

D. Remote Soil Monitoring

Sensors can be used in the soil for real time monitoring of soil quality. These sensors send the farmers updated information about the acidity, air pressure, water content and temperature of the soil. Sensors provides information about soil with centimetre level accuracy.

E. Weather Monitoring and Forecasting

Weather plays vital role in farming. Improper knowledge of weather deteriorates the crop quality and quantity. In smart farming, sensors are used to get the real time weather information. By knowing the real time information, farmers are be able to identify the crop that will sustain in that particular weather conditions.

F. Data Analysis and Future Predictions

When we use sensors for consistent monitoring of soil, weather, crops and fields, lots of data is generated. Large amount of data collected from the farmland can be analysed and used for yield prediction and future decision making for better yield production.

G. Remote Livestock Monitoring

It is a tedious task to monitor livestock. Just like crop monitoring, sensors are also used for livestock monitoring, Sensors are attached to the body of livestock and send information about the movement, stress level, health and nutrition intake of the animals to the farmers. There are also collars available with sensors which can be used to identify the location/movement of herds. Sensors are used for early detection of disease, so that animals can be treated on time. Sensors are connected to the smartphone of the farmer and send him the live information.

H. Reduce Manpower Requirement

With IoT, farmers get real time information remotely, there is no need to stay at the field. Sensors are used in the field and if some disturbing crop disease, weather condition or soil quality is found, an alert is sent to the farmer. There is no need of the farmer to be present in the fields. He can remotely monitor and control the things. All the tasks of monitoring, irrigation and crop spraying are done by IoT connected devices, so reduces the man power requirement.

VII. SMART SUPPLY CHAIN - SMART WAREHOUSES AND LOGISTICS

Food items are perishable, there is a strict need to maintain specified temperature and moisture from farm to retail. Supply chain is a complex task to be performed precisely as planned to avoid any food loss. IoT plays vital role in supply chain by providing end-to-end visibility. Sensors are used to monitor the quality of food during storage and transportation to ensure that food safety standards are maintained. Advanced sensors are used to monitor and control humidity and temperature and allow shippers to consistently monitor food containers. It allows shippers to fix the problem on time and to remove spoilage before reaching the customer. IoT has the potential to eliminate the food loss during supply chain with its proactive and timely decision-making capabilities.

IoT is also used to locate the locations of the food items during transit. Radio Frequency Identification (RFID) tags are mounted in the trucks, so that shippers can anytime locate the location of the truck. To avoid any delay in transportations of products, Global Positioning System (GPS) can be used by trucks to identify the best route based on weather conditions and traffic.

VIII. CONCLUSION

In a world of limited resources, there is a need of smart technology where automation can help to address the future challenges of feeding global population. If the productivity will not increase, we will fail to fulfil the projected demand of 2050. Use of IoT in agriculture will push the farming to next level and help in better managing food supply chain from crop management to retailers. Smart farming not only reduces the man power involvement but also reduces the excessive use of water, fertilizers, chemicals and pesticides and at the same time improves the yield quality and quantity. With smart farming, farmers will be connected to their fields like never before. Large scale research is going on in this area.

REFERENCES

1. N. Ananthi, j. Divya, M. Divya and V. Janani, *IoT Based Smart Soil Monitoring System for Agricultural Production*, IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2017.
2. C. Cambra, S. Sendra , J. Lloret and L. Garcia. *An IoT Service Oriented System for Agriculture Monitoring*, IEEE International Conference on Communications (ICC), 2017.
3. R. Dolci, *IoT Solutions for Precision Farming and Food Manufacturing: Artificial Intelligence Applications in Digital Food*, IEEE 41st Annual Computer Software and Applications Conference (COMPSAC), 2017.
4. A. Ezhilazhahi and P. Bhuvaneswa, *IoT Enabled Plant Soil Moisture Monitoring using Wireless Sensor Networks*, Third International Conference on Sensing, Signal Processing and Security (ICSSS), 2017.
5. S. Fang, L. Da Xu, Y. Zhu, J. Ahati, H. Pei, J. Yan and Z. Liu, *An Integrated System for Regional Environmental Monitoring and Management Based on Internet of Things*, IEEE Trans. Ind. Inform. 10, 1596–1605, 2014.

6. J. Gubbi, R. Buyya, S. Marusic and M. Palaniswami, *Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions*. Future Generation Computer Systems, Vol. 29, no. 7, pp. 1645-1660, 2013.
7. A. A. R. Madushanki. M. N. Halgamuge, W. A. H. S. Wirasagoda and A. Syed, *Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: A Review*, International Journal of Advanced Computer Science and Applications, Vol. 10, No. 4, 2019.
8. P. Sureephong, P. Wiangnak and S. Wicha, *The Comparison of Soil Sensors for Integrated Creation of IoT-Based Wetting Front Detector (WFD) with an Efficient Irrigation System to Support Precision Farming*, International Conference on Digital Arts, Media and Technology (ICDAMT), 2017.
9. S. Wolfert, L. Ge, C. Verdouw and M. J. Bogaart, *Big Data in Smart Farming – A Review*, Agriculture Systems, Vol 153, PP. 69-80, 2017.
10. A. Yousefpour, G. Ishigaki, R. Gour and J. P. Jue, *On Reducing IoT Service Delay via Fog Offloading*. IEEE Internet of Things Journal, Vols. 998 - 1010, No. 2, 2018.
11. W. Zhao, S. Lin, J. Han, R. Xu and L. Hou, *Design and Implementation of Smart Irrigation System Based on LoRa*. IEEE Globecom Workshops, 2017.
12. C.C. Baseca, S. Sendra, J. Lloret and J. Tomas (2019). A Smart Decision System for Digital Farming. Agronomy, Vol 9, Issue 5. Available https://www.mdpi.com/2073-4395/9/5/216.
13. FAO (2019). The State of Food Security and Nutrition in the World. Available http://www.fao.org/state-of-food-security-nutrition/en/.
14. FAO (March 2019). Scarcity – One of the Greatest Challenges of Our Time. Available http://www.fao.org/fao-stories/article/en/c/1185405/.
15. FAO (2019). Food Loss and Food Waste. Available http://www.fao.org/food-loss-and-food-waste/en/.
16. FAO (2009). Global Agriculture Towards 2050. Available http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf.
17. FICCI (2018). Agri Start-Ups: Innovation for Boosting the Future of Agriculture in India. Available http://ficci.in/spdocument/23049/Agri-start-ups-Knowledge-report-ficci.pdf.
18. Focus (2017). Smart Farming. Available https://www.iso.org/files/live/sites/isoorg/files/news/magazine/ISOfocus%20(2013-NOW)/en/2017/ISOfocus_122/ISOfocus_122_EN.pdf.
19. R. K. Kodali, N. Rawat and L. Boppana (2014). WSN Sensors for Precision Agriculture. In: Region 10 Symposium. IEEE, pp. 651–656. Available https://doi.org/10.1109/TENCONSpring.2014.686311.
20. A. Waltera, R. Fingerb, R. Huberb and N. Buchmanna, (2017). Smart Farming is Key to Developing Sustainable Agriculture. PNAS, Vol. 114, no. 24. Available https://pdfs.semanticscholar.org/d659/e7058a32f58db52cd44fd9ddc5c5f94bd0d7.pdf
21. WHO (2019), Food Safety. Available https://www.who.int/news-room/fact-sheets/detail/food-safety.

AUTHOR PROFILE

Dr. Shalini Vermani is Associate Professor and Area Head of IT and Operations Department in Apeejay School of Management, New Delhi. She has more than 18 years of rich academic and research experience. She has published several research papers in National and International Journals and also authored two books – one on 'Discrete Mathematical Structures' published by 'Imperial college Press', London and another on 'An Elementary Approach to Design and Analysis of Algorithms' published by 'World Scientific', Singapore. She is also the reviewer of various Journals. Her areas of interest are: Cryptography, IoT, Information Security and Project Management.