IOT PERSPECTIVES IN THE INDIAN AGRICULTURE SECTOR

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Abstract - This paper explores the prospect of introducing a smart farming product solution i.e. FarmSight to solve India's existing low crop yield problems. India's crop failure and low farm yield is an apparent problem with statistics from Food and Agricultural Organization of the United Nations highlighting that the share of the agricultural sector in India's economy is progressively declining at a rapid rate and is currently less than 15%. Various factors come into play - climate change issues like droughts and heavy rainfall are few of the main reasons for a high crop failure rate and low crop yield across farms in India. As a result, there is a need to improve the agricultural practices in India to improve the efficiency across the farmlands for a sustainable and diversified agricultural sector. In order to alleviate India's low crop productivity problem, harnessing the power of Internet of Things and Big Data Analytics, with a core focus on studying and collecting data about the various elements of the crops and farms across the Indian landscape to deliver better farming practices is the key. Benefits of this technological solution can be applied and implemented across the entire Indian landscape. Benefits include but are not limited to improving the crop yield of the farms across India, accurate assessment of fertilizers needed, improved water quality, improved soil quality, and overall improved crop health. FarmSight i.e. the product solution itself will perform real time analysis of the farming field, crop quality, soil, and water quality and relaying that information to the farmer. Thereby providing quick, real time updates to the farmers so that they are aware of the farm and crop conditions across their farming landscape at all times.

Index Terms - Agronomical Data, Big Data Analytics, Internet of Things, Precision Agriculture, Smart Farming

I. INTRODUCTION

India was one of the founding members of the Food and Agriculture Organization of the United Nations (FAO) in
1945 and has since then come a long way from initially being a low-income food-deficient country [1] [2] [3] to now becoming a global agricultural powerhouse according to the World Bank [4] [5] [6]. Today, India is known for being highly self sufficient in wheat and rice, while also exporting a variety of food products [7]. According to the United Nations [1] [8], India is also known to stock up to 60 million tonnes of food grain buffers. Agriculture is highly pivotal to the Indian economy [6] [9]. Currently, India is one of the top two farm producing countries in the world [10]. The agricultural industry itself is responsible for providing 52 percent (approximately) of the total jobs in India and its contribution to the GDP is about 18.1 percent at present [11]. While looking at the statistics, it is known that more than 70% of the rural households in India depend on agriculture as their source of living [12] [13] as it is responsible for providing jobs to more than 60% of the Indian population [14]. Indian agriculture has seen incredible growth over the past few decades, wherein the production of food grain has increased from a mere 51 million tonnes in the year 1950-51 to a massive 250 million tonnes during 2011-12, which is the highest ever since the independence [5] [15] [16].
The agriculture industry is spread out across 43 percent of India's total geographical area. Figure 1. below gives an industry snapshot of the Indian agricultural industry [8], wherein the top crop producing states are - Uttar Pradesh, Rajasthan, Gujarat, Karnataka, Andhra Pradesh, and West Bengal [17] [18]. The top crops produced are: wheat, rice, maize, and pulses. Out of the total agricultural workforce, 31% are female farmers, while 69% are male farmers [11] [19] [18]. The total allocation for the agricultural sector has rapidly increased to 24% (year on year) and is estimated at USD 28.1 billion [20] [21]. Out of all total geographical land, 43% of it is used for agricultural activities [14], and agricultural sector is also responsible for providing jobs to more than 60% of the Indian population [11] [22].

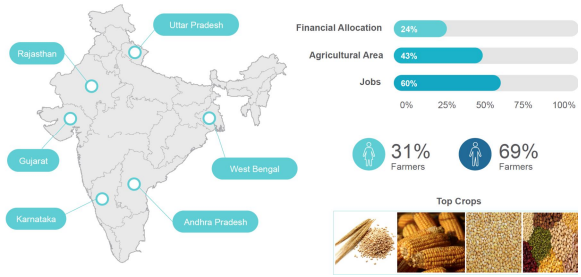

Figure 1. Indian Agricultural Industry (Source: Ministry of Agriculture, Government of India)

II. METHODOLOGY

A methodological review of past literature is a highly critical step for academic research. The literature review approach was used as the preferred method for conducting research as this approach is deemed most appropriate for understanding the current agricultural needs of Indian economy, the underlying causes of the problems, the current government and technological initiatives to meet the farming needs, and hence propose innovative yet novel solutions to suit the Indian market. A range of academic publications, journals, & news articles were analysed, synthesized, and evaluated to propose an innovative approach to

solve India's existing agricultural problems via embracing IoT.

III. LITERATURE REVIEW

A. Challenges in the Indian Agricultural Landscape

Agriculture is highly dependent on natural elements in India even today. If there is any variation in these natural elements, then it has a negative impact on the crop yield [27] [28]. Crop yield is known as the amount of crop (which could be grains, vegetables or fruits) that is produced per unit of fertile land [19]. The crop yield of the farms in India is one of the lowest globally [29] [30]. According to a survey conducted by the Economic Times, India's average yield in 2013 was 3075 kg/ha, which is lower than the global average of 3257 kg/ha [31] [18]. This is also highlighted in Figure 2 below [32] [24] [35]. There are many underlying factors that are responsible for the low productivity. According to a report by the Economic Times [19], it is known that water is used inefficiently for agricultural activities, which thereby affects the productivity. India is known to use 2 to 4 times more water for producing one unit of a major food crop than countries like Brazil or China [32].

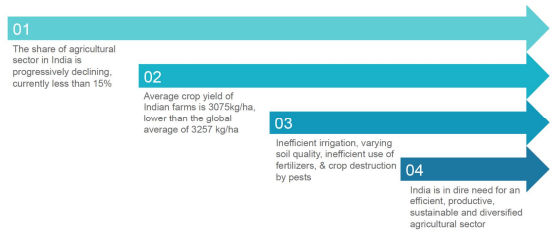

Figure 2. Key Challenges in Indian Agricultural Industry (Source: World Bank)

Most of the land used to growing pulses is not irrigated and also the subsidies on power for the agricultural sector sabotage the efficient use of water as it incentivizes wastefulness and has expedited the decline of water tables in India [14] [17] [7] [33]. Apart from availability of water, the soil quality, efficient use of fertilizers as well as crop destruction by pests are few of the key problems that the Indian farmers are currently facing [34]. This is where techniques like smart farming, powered by Internet of Things (IoT) can play a pivotal role in removing or reducing the impact of these factors in India [35] [36] [8].

B. Key Priority Areas

India must emphasize on sustaining the agricultural environment while also focusing on the future agricultural productivity [5]. While over pumping of water results in falling groundwater levels, on the contrary, water logging has led to a build up of salts in soils used for irrigation [22]. Climate change is another thing that needs to be taken into account, especially droughts, which have led to crop failures and farmers committing suicides at a large scale in the past in India [7]. This is also highlighted in Figure 3 below.

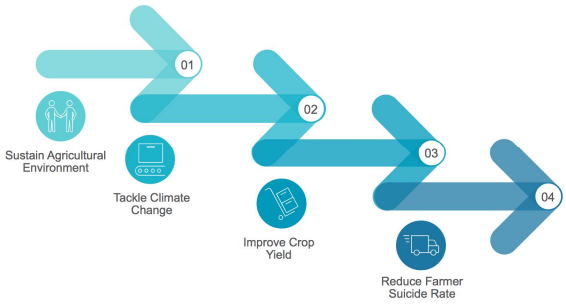

Figure 3. Key Priority Areas - Indian Agricultural (Source: Ministry of Agriculture)

C. Smart Agriculture - A Government of India Initiative

India is progressing towards becoming a digital economy [21] [16] [37]. The Internet of things (IoT) is set to transform the digital landscape in India and the Government of India is extremely supportive of this cause [38]. The Ministry of Communication and Information Technology released a policy on IoT in 2015 [17]. The draft policy gives further details about the impact of digital transformation and IoT on the Indian economy. IoT has the potential to automate solutions faced by numerous industries, agriculture being one of those key industries. The policy has been made with the goal to make the Indian IoT industry worth USD 15 billion by 2020 [14] and also increase the number of connected device from 200 million currently to 2.7 billion by the year 2020 [34] [11] [18]. The policy initiatives by Indian Government are highlighted in Figure 4 below [19] [42].

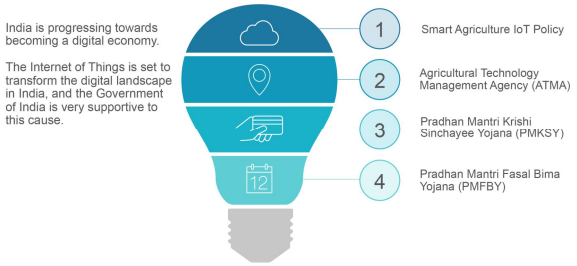

Figure 4. - Farming Policy Initiatives by Government of India (Source: Ministry of Agriculture)

In the draft policy report enlists various elements about the digital transformation and the impact of IoT on the Indian economy [1] [19]. The government of India has also strongly emphasized on the vision of digitalization of the Indian farming landscape in section 5.1.6 [24]. The key focus areas identified for smart farming in the policy are:

i) **Precision Farming:** It involves monitoring the soil and analyzing the moisture levels, vibrations, density as well as pests in order to detect patterns for different agricultural conditions [24].

ii) **Data Insights for Farmers:** To give data analytical insights for conditions like requirements for storage conditions and pest control [24].
iii) **IoT Enabled Farming Tools:** This could help in smart pest control and other insecticides [24].

D. Global Smart Farming Industry

United Nation has predicted that the world population is expected to rise from 6.8 billion today to 9.1 billion in 2050. This also means that the food production must be raised to feed the ever-increasing population [35]. The agriculture industry is known to be responsible for the human needs (around food, energy and shelter). Currently, the global agricultural industry is comprised of less than 5 percent of the combined GDPs of the world [36]. The bureau of labor statistics predicts that the human employment in the agricultural industry is projected to fall by 3 percent by the year 2022 [2]. In such a situation, agricultural modernization is something that the farming industry must look into in order to not only sustain crop productivity but also increase the crop yield [39]. The key countries in the global precision farming industry are highlighted below in Figure 5. [12] [47] [45].

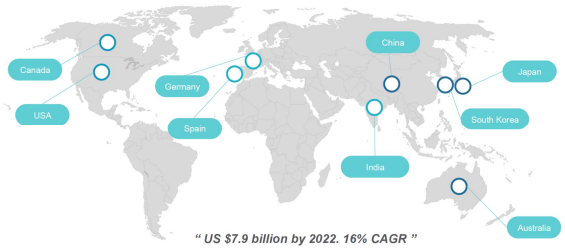

Figure 5. - Global Precision Farming Industry Snapshot (Source: World Economic Forum)

Embracing IoT has uncovered new ways, which has enabled farmers to tap into the full potential of crop yield and productivity while also diminishing the challenges that have led to crop failures or have hampered crop growth in the past [5]. In order to understand how IoT can change the way farming is done, it is important to understand what IoT is. Internet of Things is a technology expands the boundaries and limits of the Internet connectivity beyond digital devices to the realms of physical objects [19]. IoT is responsible for enabling communication between physical objects, digital devices as well as other systems. The data that is collected as a part of the process can be shared between either - person-to-person, machines to person, or machine to machine [32]. This data is actually stored and managed using the cloud [1]. With the implementation of IoT in the agricultural landscape, devices like remote valves, pest control mechanisms, weather forecasts, storage of food, monitoring system and transportation data can all be connected and the information collection can be looped in and exchanged via sensors [9]. This information can then be made available to the farmers via means of a mobile application [4].

The connected systems allow the farmers to have an integrated and multidimensional view of the farming activities, which thereby enables a deeper understanding of the whole farming ecosystem. There are many ways via which IoT can make agricultural farming more profitable and crop production healthier than before. It includes deciding which crop to best grow on a specific piece of land or on a specific type of soil type [27], using IoT enabled unmanned aerial vehicles (UAV) to smarter crop irrigation options using humidity sensors, water valves and monitoring systems [29] to getting accurate weather forecasts in real time and pre planning different agricultural activities [28] to many other techniques.

Smart farming ecosystem comprises of the following [20]:

i) **Technology Providers:** This comprises of different provides encompassing - wireless connectivity to sensors, machine to machine solutions, data analytical systems, decision support systems, smartphone applications as well as geo-mapping applications [20].
ii) **Agricultural Equipment Providers:** This includes tractors, robots, farm buildings, seeds, feeds as well as being a proficient expert in crop management as well as animal husbandry [20].
iii) **Customers:** The customers are foremost the farmers, as well as farming associations and cooperatives [20].
iv) **Influencers:** They are the market leaders who influence the market, are responsible for setting prices into which the farmers as well as the growers sell and market their products [20] [39].

The variety of stakeholders involved in the agricultural landscape is really broad and includes big businesses, financial companies, engineering companies, chemical enterprises, food retailers as well as various industry associations [20] [4]. Figure 6 below shows various technologies involved in smart farming landscape [20]:

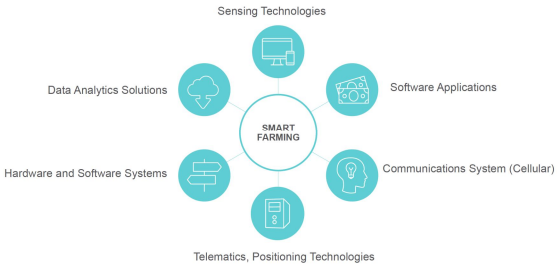

Figure 6. - Key Technologies in Smart Farming (Source - Beesham Research)

E. Benefits of Precision Farming

Precision farming or agriculture has been used in many parts of the world and has been known to allow

farmers to increase their crop yields whilst using low amount of inputs like - water, seeds and fertilizers [40] [42]. It maps out fields and deploys sensors across agricultural landscape to understand the crops at a very micro level, the insights are further used to safeguard resources and lessen the impact on the surrounding environment [42] [40]. This model has the potential to disrupt the Indian agriculture ecosystem and also help farmers improve the productivity and yield of the crops.

Precision farming uses a range of technologies, as also shown in Figure 6 above. It makes use of technologies like GPS services, servers and big data to optimise crop yields. Data and ICT driven decisions provide granular details about the farming and cropping techniques [32] [6]. For machine to machine systems, IT systems are used to collect, collate, analyse the data about - soil quality, crop behaviour, machine status, storage tank systems and remote sites. Farming professionals then use these data insights to drive more efficient farming decisions and thereby improving the crop yield. Other benefits and advantages that precision farming can bring to the agricultural landscape are - smart packaging of fertilizers and seeds etc.

DISCUSSION

Keeping precision farming techniques in mind while also analysing the challenges faced in the Indian agricultural landscape [1] [23], the proposed product is FarmSight, and will comprise of a network of different sensors across an agricultural farmland [5]. The sensors will have multiple uses, which includes - providing weather updates, monitoring the crop health, checking the level of water in the soil along with the level of nutrients and analysing the soil health [22]. The pool of data collected is then sent to the servers, where it will be analysed and data driven insights will be represented via forms of graphs, maps any other pictorial representation which is easy to understand for farmers. Farmers can use the portal to access these data insights confidentially. Data can also be further analysed to do predictive analytics and suggest more precise and efficient farming techniques.

The proposed product FarmSight also has a mobile application, which is available to the farmers as also seen in the conceptual design in Figure 7 below. The farmers can view the collected agronomical data insights as well as predictive data insights via the application. The farmers will also be notified via the mobile application for crop health alerts, pest control, and warehouse inventory management alerts as also shown below. Key mobile application functionalities include:

i) Viewing crop health details (nutrient levels, pH levels etc.) via crop scouting functionality.
ii) Managing fertilizer and pesticides needs for the farm via the application effectively.
iii) Checking and managing water levels and soil health across the farm, and automating the irrigation process.
iv) Tracking harvesting records, and checking warehouse and bin inventories for the same.

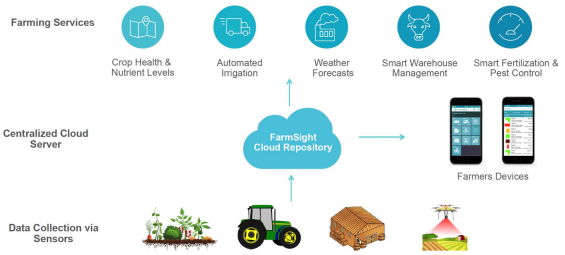

Figure 7. FarmSight Architecture

F. Benefits Delivered

This comprehensive product solution for FarmSight delivers a range of benefits, which not only differentiates this product from the existing agricultural competitors in the IoT space, but also provides the product a competitive edge in the market since it is the first one of its kind. This product will impact multiple stakeholders involved with the project in positive ways. The benefits delivered by the product can be grouped into - benefits to the farmers, benefits to agricultural stakeholders, and benefits to the Indian agricultural sector and economy; which are enlisted below:

i. Benefits to the Farmers:

- Efficient water irrigation system and more control over water flow
- Accurate assessment of fertilizers needed
- Improved water quality managed
- Improved soil quality, soil humidity
- Efficient and accurate pest control and monitoring
- Better insights about weather forecasts and better planning
- Improved evaluation of crop health
- Improved crop productivity
- Accurate assessment of the level of nutrients in soil and crops
- Efficient monitoring and controlling of food storage and safety in warehouses

ii. Benefits to the Agricultural Stakeholders:

The different agricultural stakeholders involved with this project would include the following Indian government department and agencies:

- Ministry of Agriculture and Farmers Welfare, Indian Government
- Agricultural Technology Management Agency
- Pradhan Mantri Krishi Sinchayee Yojana,

India
- Pradhan Mantri Fasal Bima Yojana
- Paramparagat Krishi Vikas Yojana
- Farming Associations and Cooperatives

The benefits to these stakeholders are:
- Reduced crop failure rate
- Increase in crop productivity
- Improved quality of farming practices in India

iii. Benefits to the Indian Agricultural Sector and Economy:
- Improved quality of farming practices in India
- Improved crop productivity
- Improved rate of India's agricultural sector in the Indian economy

The raw data can be utilized by the stakeholders to track, estimate, and/or predict the following information, which in turn is beneficial to their respective organizations:
i) Predictive insights about crop health
ii) Predictive insights about development of pathogens or fungus on plants
iii) Predictive irrigation insights
iv) Analyse crop growth trends and patterns
v) Analyse and aggregate the data about different farming practices across Indian landscape

G. Business Environment - Target Market & Traction

FarmSight is targeted at mid to high-income farmers in India, which constitute about 0.1% of the total agricultural farming workforce, and the estimated market size is 1.2 million farmers [27] [16] [20] [50] [25]. FarmSight will also be targeting farming associations, cooperatives and foundations across India [30].

According to a report by Yale University Climate Connections and United Nations, it is projected that the world must produce 60% more food to meet the demands of the ever-growing population along with the shifting and more diverse patterns of consumption. The Australian Trade and Investment Commission has predicted that the demand for Indian agrifood will increase by 136 percent by 2050. The strong economic growth in India is expected to continue over the coming few decades [1] [4] [2].

Figure 8 below shows the estimated traction in the target market in India [17] [18] [19] [51]. Currently there are 482 million farmers in India [12] [13], and this industry is growing at 0.2% each year [38] [15], and the growth in the Indian agricultural workforce is estimated to be ~600 million farmers by 2020 [51]. There are many drivers of food demand and consumption in India, and this has increased rapidly over the past few decades as reported by the Australian Department of Agriculture. The United Nations Population Division has also projected that India's population growth rate will be averaged at 0.5 percent a year between 2030 and 2050.

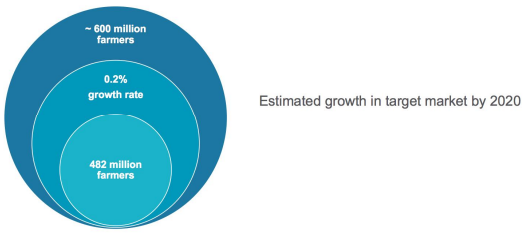

Figure 8. Target Market Traction Snapshot (Source - Census India & Ministry of Agriculture, Government of India)

India has emerged as one of the fastest growing economies in the world in the past few decades [4]. The GDP has increased at a rate of 6.6%, as reported by International Monetary Fund (IMF) [4]. With the increase of income levels and diversification of diet patterns, food consumption levels in India are rising per person for dairy products, fruits and vegetables [23].

In conclusion, there is a huge potential for the growth of smart farming initiative in the Indian agricultural landscape. The increasing food demands as well as need to improve falling crop productivity can both be tackled with the precision farming initiative.

H. Demand of Indian Agricultural Products

According to the World Population Statistics [2], India's population is expected to reach 1.39 billion by the year 2021 [4] [2]. Population is one of the key demand drivers of growth of agriculture industry in India. The graph below by the World Population Statistics [39] [20] [4], shows the growth in the Indian population over years along with the future projections as well.

I. Growth Drivers in the Indian Agricultural Landscape

India is a strong player in the global agricultural industry and there are three key drivers that are driving growth in this sector [2], which are: Demand Side Drivers, Supply Side Drivers and Policy Support Drivers [2]. The demand side drivers include a rapid increase in income and population growth as also discussed before. It also includes an increase in the number of exports across India and also favourable agricultural demo-graphs across the country [2] [4]. A lot of emphasis has been given on the policy support and government initiatives that support farmers and smart farming initiatives. These schemes are also aimed at increasing the minimum support price and grow the institutional credit for farmers [4].

Lastly, on the supply side drivers, initiatives like mechanization, technology driven farming, hybrid and genetically modified seeds and green revolution in India has spurred growth across the Indian

agricultural landscape [2].

J. FarmSight - Target Customers

FarmSight will be targeting mid to high income farmers across the Indian agricultural landscape, which can derive maximum benefits for this product solution, and will be able to implement and use it well [15] [49]. Mid to high-income farmers in India constitute about 0.1% of the total agricultural farming workforce, and the estimated market size is 1.2 million farmers [51] [48]. This is also shown in Figure 9 below. FarmSight will also be targeting farming associations, cooperatives and foundations across India [21] [51] [19].

Figure 9. FarmSight Target Market (Source - Census India)

To get deeper insights into the agricultural income across different households in India, Table 1 below shows the income sources for different farming households across India [35] [24], and agricultural activity [2] [3] is the biggest source of income for farming households wherein 91% of the households have been reporting having income coming from agriculture as the source [24].

Table 1. Income sources of farm households by income quintile

Income quintile	Per capita income (₹/annum)	Income sources							
		Agriculture		Livestock		Wages and salaries		Non-farm business	
		Partici-pation rate (%)	Share in income (%)	Partici-pation rate (%)	Share in income (%)	Partici-pation rate (%)	Share in income (%)	Partici-pation rate (%)	Share in income (%)
Lowest	2503	89.8	49.2	54.6	18.7	42.2	28.4	6.6	3.7
Second	4079	90.2	45.2	61.1	19.2	50.4	31.2	8.0	4.4
Third	6162	90.1	43.8	66.2	19.6	51.0	30.1	10.0	6.4
Fourth	9834	90.8	45.3	70.4	19.2	48.0	25.2	16.1	10.3
Highest	32324	93.5	38.4	72.3	10.7	36.8	13.5	30.4	37.4
All	10411	90.9	41.4	64.9	14.4	45.7	19.8	14.2	24.4

Table 1. - Income Sources for Farming Households in India (Source - Ministry of Agriculture, India)

Other sources of income include non-farm business related activities, which share 24.4% of the total income share, and also is the second largest source of income for farmers after agricultural activities [4] [52]. It has been observed that agriculture is a major source of income for the lower 20% of the households in India [52] [28] [2], which accounts for almost half of the total income of these farming households [8] [53].

Additionally, it is known that the following states are the top crop producing states in India [43] [29], and the product roll out would target the following 6 states - Uttar Pradesh, West Bengal, Karnataka, Gujarat, and Rajasthan. These six main states would the focus of expansion during the initial product deployment roll out phase [50] [53].

To conclude, it is evident from above that agricultural activities is the highest source of income for farmers across the Indian landscape, and hence providing a precision farming product to mid and high income farmers is a must to improve the crop yield and productivity of farmlands [50]. The low income farmers can be targeted at a later stage, to reach out and provide this technology product solution to cater to their farming needs as well [53].

K. Existing Players in Global Precision Farming Landscape

Several competitor products exist in the market. There are three direct competitors for FarmSight in the agri-tech precision farming landscape, which is discussed below in details.

a) FarMobile: It is a US based farm data company, which helps farmers take ownership of their data immediately. Their product offerings are not only used to store and share but also to sell valuable agronomic and machine data to interested third parties. The whole essence to realise that data is the most important element that a technology enabled farm produces in today's disruptive world [40] [31].

The product offering, namely PUC, is used to collection data, which can digitally transform the way farming is done. The data is then used to boost operational efficiency along with going deeper to get new insights from an agronomical perspective [41] [20]. The data and insights are available to farmers via the FarMobile Application, which organises the insights as dashboards and reports for analytical purposes and use [20].

b) OnFarm: It is a software-as-a-service (SaaS) company with a range of farm hardware technologies - which are used to collect data from farmland sensors and devices, the data collected is then analysed to perform data driven decisions, do farm wide scheduling, and give alerts to farmers [5].

c) Farm(X): This organisation focuses on precision irrigation management. The FarmX sensors are used to measure water stress by measuring the plant, soil, and environmental variables. Then the data collected is used to do predictive analytics to deliver real time irrigation insights, which can be effectively used to not only save water across farmlands but also increase the crop yield and productivity [3].

L. FarmSight - Competitive Edge

The main competitors to the proposed product solution i.e. FarmSight have been discussed in details above. The competitors have strong product features and provide a range of high quality services for data

collection, insights, and management. However, the competitors don't provide many additional features to measure the crop health, nutrient levels, insights about pest and pathogen control management, agri-bots for farm-work, survey drone management, and also warehouse management capabilities.

Apart from the farming sensors (as also provided by our competitors), the proposed product i.e. FarmSight will also provide warehouse sensors, which keeps a track record of the stock inside the warehouse for - crop, pesticides, and fertilizers. Farmers are notified via the mobile application if a certain product or crop is getting depleted along with suggestive measures i.e. suggestions on where to buy the pesticides and fertilizers, and also where to sell the crops in order to obtain maximum profit. The application will also be able to provide the farmers with deals, offers, and discounts related to farming products and agricultural equipment.

The proposed solution is providing end-to-end farming solution using Internet of Things to the farmers. The farmers will be able to get insights about commonly asked questions like - what to grow, how to grow a specific product, when is the best time to grow to name a few. The single platform provided by the proposed product will assist the farmers in everything i.e. farming, harvesting, irrigation, pest & pathogen control, and fertilizer updates and options. Farmers will also get access to different dynamic pricing models as per their farming needs, along with a free trial period wherein they can use the product for one month absolutely free of charge.

Quick response services will be provided to address customer queries within 24 hours, and a technical representative will also be sent to the farm site to assist the farmers if the problem persists. These distinctive features are what sets the FarmSight apart from its competitors and is the underlying basis for its competitive advantage both in the Indian as well as the global market.

CONCLUSION

As outlined from the research, the low crop yield of the farms in India is real and happening, climate change has triggered droughts and inefficient use of water resources have led to crop failures and farmers committing suicide in the Indian agricultural landscape. Factors (apart from crop failures) include drought, floods, farmers in debt are few of the most common reasons why Indian farmers commit suicide [60] [25], and Indian agricultural industry has experienced about 300,000 farmers committing suicide [9] [31] in the past 20 years, according to a report by the Indian government [60]. With FarmSight i.e. the proposed product solution, real time data driven insights and predictions will be provided to the farmers in the Indian agricultural landscape. Thereby improving the crop productivity as well as positively impacting the Indian agricultural brand on a global front.

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