Agricultural Economics Research Review 2022, 35 (Conference Number), 101-108
DOI: 10.5958/0974-0279.2022.00022.2

Patent landscape for Internet of Things (IoT) in agriculture in India

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Abstract Innovative digital technologies have huge potential to provide solutions for the many complex problems in agriculture. IoT based technological applications are now been accepted even by small hold farmers for judicious use of resources with precision and better predictability. With improved digital infrastructure across the country, the agritech startups offer innovative IoT based smart solutions addressing the problems of farmers. Many such agritech startups have made their mark in the market with their own patented technologies. In this paper patent analytics is used to measure the current status, emerging trends in technology development in IoT landscape for agriculture applications and growth prospects of agritech startups. States of Karnataka, Maharashtra, Tamil Nadu and Telangana with favorable startup policies see greater concentration of these agristartups.

Keywords Internet of Things, patents, agritech, startups

JEL codes O 34, O 31, O 13, M 13, Q 16

Introduction

The concept of IoT or 4th Industrial Revolution interconnects physical things offering Human to Machine (H2M) communication over the existing model of Machine to Machine (M2M) communication. A study by (Mackinsey 2015) has estimated the potential economic impact of IoT to be $ 4.0 trillion to $ 11 trillion by 2025 with large number of applications in health care, manufacturing, power, urban security, vehicles and agriculture. In the market, Google has spent $5.5 billion in acquiring IoT based companies like Nest, Boston Dynamics, Waze and Dropcam indicating the importance of IoT based technologies (LexInnova 2014). In such a dynamic and lucrative, competitive market, protection of intellectual property (IP) by the creators and owners becomes vital and often an important business strategy to enter the markets (Kock Michael 2013). Any assessment of the IP landscape becomes an important exercise for the players specially the startups before entering this market (Teixeira and Ferrerira 2019).

In recent years increased acceptance of digital technologies by the stakeholders in agriculture including farmers is attracting attention of policymakers, industry and even startups (Coble et al. 2018; DiPrinzio et al. 2018; Waltz 2017). Leveraging the use of platform based IoT for solutions across each point of agri-value chains has been found to be more remunerative and also sets in the judicious use of resources with precision and better predictability (Khanna and Kaur 2019; Verma et al. 2019; Ojha, Misra and Raghuwanshi 2015). Of late, smart agriculture practices are being adopted by many farmers even in third world countries including India (Kangogo, Dentoni and Bijman 2021). This system of automated and directed information technology applied with the IoT is essentially a combined approach with internet and wireless communications, Remote Monitoring System (RMS) etc. with applications for better and precise use of inputs at targets and predict better outputs leading to advisories on price and profitable decisions at market levels (Ayaz et al. 2019).

Thus, these technologies have potential to boost the efforts in improving the supply chain, marketing and productivity ultimately leading to Doubling Farmers Income and improved economic stimulus to agriculture under Atma Nirbhar Bharat. The Government of India (GoI) is encouraging private investments in agriculture. With the government support and improved digital infrastructure, the agritech startups bring innovation with the combination of new-age technologies such as the Internet of Things (IoT), data analytics, artificial intelligence (AI) and remote sensing and offer solutions addressing the pain points of farmers (Anupam Anand, and Saravanan 2019: Ernst & Young 2020; Murray 2020). Many of these agri startups are making their mark with their own patented technologies (Inc42's Startup Watchlist 2020).

Patent informatics is now a well-known tool for analysis of patents for making assessments about emerging technology (Jaffe and Trajtenberg 2002). It can be regarded as an important indicator of the broader path of innovation in an emerging field as patents reveal information about inventors as well as type of inventions and their applications (Gupta et al. 2020, Kalpana, Shrivastava and Rao 2013). Patent analysis has often been used to measure current status, emerging trends in technology development and for future strategic planning for the growth of organizations (Aristodemou and Tietze 2018; Hullmann and Meyer 2003).

The present study was undertaken to (i) depict the trajectory of IP landscape of the IoT based patents in agriculture in the Indian context, and (ii) upcoming Agritech startups holding IoT based patents and their growth prospects.

Methodology

Patents related to internet of things applications in agriculture are collected from Patentscope, the World Intellectual Property Organization (WIPO) database (wipo.int/patentscope/en/). A set of subject specific keywords and standardized search strings are identified; standardized search strings made with truncation, appropriate Boolean operators and identified keywords to perform search of patents (patent title, abstract, claims). The WIPO guide which identifies, explains large number of perceptions on patent analysis and methodology on how to track the different types of analysis on patent data was studied (Trippe 2015).

Retrieved relevant records[1] were then subjected to full text search of patents (patent title, abstract, claims and description) and scrutiny through International Patent Classification (IPC). IPC is a hierarchical classification system used primarily to classify and search patent documents according to the technical fields they pertain. It is a very powerful tool for searching patent related databases enabling the user to locate the appropriate technology in the search. All the search results are combined and duplicates are removed, and temporary work sheet is exported is CSV format. A set of patent documents are retrieved belonging to 128 patent families for India. Only one priority member per FAMPAT family is analyzed i.e. each patent represents one priority document of the respective patent family. FAMPAT is the worldwide collection of patents grouped by invention based families containing bibliographic information, full text and legal status. The patent search data is up to 13th November, 2020. The data on investment raised by startups having patents in different IoT applications were collected from various sources.

Results and discussion

Leading countries with IoT patents in agriculture

It was observed that about 2835 patent publications with the keywords ("Internet of Things" OR "IoT") AND ("Agricultur*" OR "Farm*") are spearheading the IoT technologies in agriculture worldwide.

The patenting activity seems to be more concentrated with China, and United States of America. Figure 1 depicts the leading countries with China at the top with 62% patents followed by US with 20% patents. India is contributing to about 4.8% patents. About 8.7% patents are the PCT filings indicating the interest of the R&D players growing in various geographical markets. Kshetri (2017) and Friedman (2014) report the leading position of China in IoT technologies.

Patent time line analysis

Globally the patenting activity in the IoT based applications in agriculture started in 2011 but more actively from 2014 onwards (LexInnova 2014). In

[1]Include all filed patent documents.

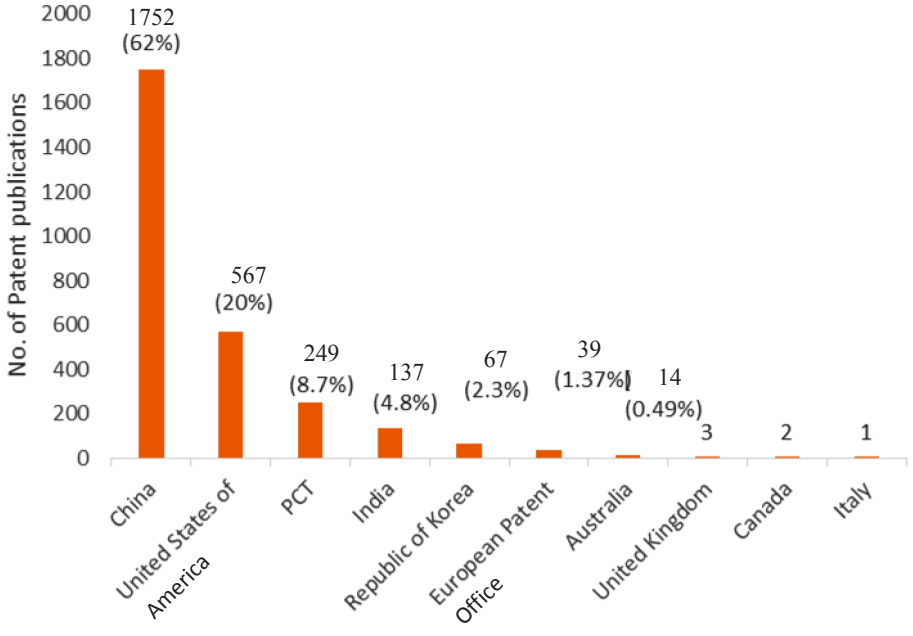

Figure 1 Distribution of agriculture/farm related IoT based patents in earliest priority country (n=2835)

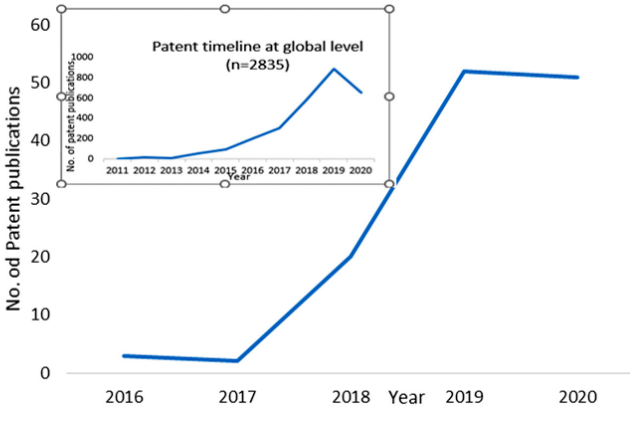

Figure 2 Yearly filing of patent (n= 128, one priority document per family) in India, inset shows yearly filing trend at global level

India, patents with IoT applications in agriculture sector started in 2016 and is rising in accordance with the global trend as shown in Figure 2. About 137 patents were found through WIPO database Patentscope, which was screened and of this, 128 relevant patents were analysed.

Taxonomy of patents

Seamless incorporation of IoT and the wireless sensors in smart agriculture has raised agriculture to newer levels. It was found maximum patents in Resource Management followed by Crop Monitoring and Pest Management (Figure 3).

About 42% of the patent applications represent in the area of resource management including soil sampling and mapping. The distance and depth for sowing the seed efficiently can be decided using IoT based sensors and vision -based technologies. Many traditional farming issues, like yield optimization, drought response, land suitability, irrigation, and pest control can be improved with the IoT based solutions and practicing smart agriculture techniques.

About 13% patents represent crop monitoring and 7% in pest management. The usage of pesticides by growers are slashed significantly by using these IoT based intelligent devices e.g. wireless sensors, robots and drones, with precise spotting of crop enemies. In comparison to traditional farming practices modern IoT-based pest management provides real-time monitoring, modeling, disease forecasting thus proving to be more effective. Patent applications in the area of Veterinary/Dairy, Prediction & Green houses are between 5-3% each. An IoT-based greenhouse remotely monitor the inside parameters viz humidity, temperature, light, and pressure etc.

Top Assignees

Figure 4 shows the distribution of top 10 assignees in the IoT based patents in agriculture sector. Applicants

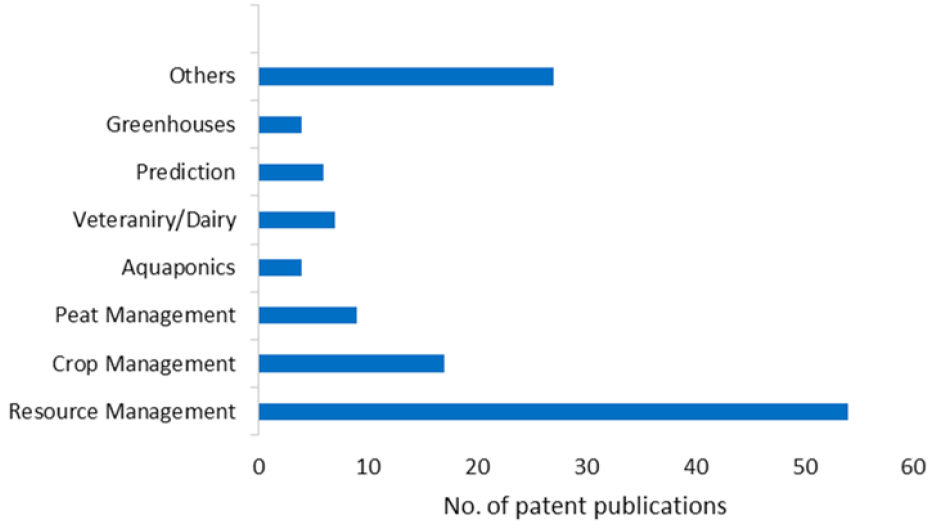

Figure 3 Categorization of IoT based patents in agriculture (n=128)

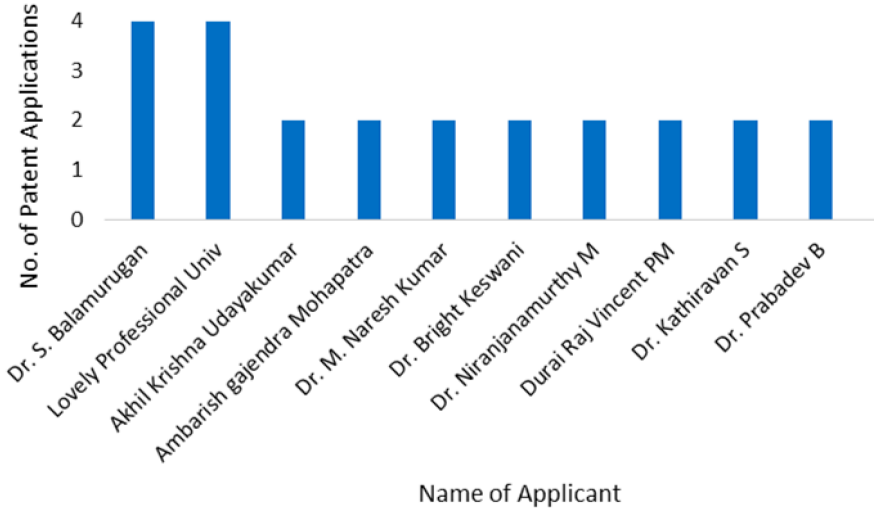

Figure 4 Top 10 Assignees in IoT application in agriculture (n=102)

Dr. Balamurugan and Lovely Professional University are at the top with 04 patents each followed by many applicants with individual patents. Dr. Balamurugan's patent No. IN283299301 is for "IoT based security system and method for smart agriculture", IN296579954 is "IoT based intelligent pesticide man machine system for agricultural purposes", IN297816610 is "IoT and cloud based agricultural data management system and method for effective planting and breeding", IN300871671 is about "system and method of smart drones for smart farming". The patents filed by Lovely Professional University, Punjab is mainly IN283300055, IN283164479 for "Smart surveillance system for water distribution in agriculture field". IN283165823 is about "farm assist: an intelligent farmer assistant for selling crop" and IN283176894 is" an IoT enabled system for plant health monitoring system and image processing".

Distribution of IPC codes

The distribution of the patents is mainly in the IPC A01G, G06Q, H04L & G01N indicating the patents applied in the technology areas of horticulture, floriculture, data processing systems, forecasting etc. (Table 1).

Table1 Distribution of the Patents in the IPC Codes

S.No.	IPC	No. of patents	Technology description
1.	A01G	41	Horticulture, cultivation of vegetables, flowers, rice, fruit, vines, seaweed, forestry, watering
2.	G06Q	22	Data processing systems or methods, adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes
3.	H04L	17	Transmission of digital information
4.	G01N	10	Investigating or analysing materials by determining their chemical or physical properties
5.	A01B	9	Soil working in agriculture or forestry, parts, details or accessories of agricultural machine or implements
6.	G05B	8	Control or regulating systems in general, functional elements of such system, monitoring or testing arrangement of such systems or elements
7.	A01C	7	Planting, Sowing, Fertilizing
8.	A01K	5	Animal Husbandry, agriculture, apiculture, pisciculture, fishing, rearing or breeding animals
9.	H04W	5	Wireless communication networks
10.	A01M	4	Catching, trapping or scarring of animals, apparatus for destruction of noxious animals or noxious plants

IoT based startups in agritech

The patent landscape of IoT patents in agriculture in India shows that the number of patents filed in India are majority from individual inventors. This has resulted in many startups emerging in this sector with innovative ideas (Lim, Kwon and Lee 2018). The entrepreneurial landscape of India has grown and is presently the 3rd leading startup ecosystem especially due to the support of the Startup India Scheme, Ministry of Commerce and Industry, GoI and NITI Aayog's Atal Innovation Mission. As per the (NASSCOM July 2019) report there are about >450 agri-startups in India, every 9th agritech startup in the world is from India. Agritech in India is continuously attracting interest from startups and investors. The key target segments of majority of Agritech startups are Big Data analytics, Farming as a service, Market linkage models and IoT. As the Agritech ecosystem is maturing in India, significant growth in terms of investments is observed. Some of the prominent investors in the Agritech sectors are Omnivore, CIIE.CO, Accel, Ankur Capital, Kalari Capital, Aavishkaar Capital, Menterra etc. (Ernst & Young 2020, NASSCOM Report 2018).

Indian Agritech startups have received the investment of $ 1.7 billion in 2014-19 compared to $0.2 billion in previous five years (Ernst & Young 2020). International investors are investing about 80% of the capital, which attracted Indian investors who are now ready to invest in such startup innovations for better profitability. The funnel concept of investment usually starts with wide pool of potential investors and narrow down to that worth reaching out to. But, the investment pattern in agritech startups is "Bloated-in-the-Middle" investment funnel rather than broader at the mouth of the funnel indicating the absence of investment prospects in initial stages, absence of innovative business models or the emerging Agtech ecosystem is struggling to create a quality pipeline. Due to this gap funding, the startups are taking lengthier time to reach the metrics that investors expect for deploying large amount of capital, as business models take longer period to show traction. Growing trends in four key subsectors i.e., DownstreamAgTech (solutions to optimize the output supply chain and creating linkages with the end consumer), UpstreamAgTech (improving input access for the farmers through digitalization of the input supply chain) , PrecisionAgTech (use of digital data to target smart farming) and AgFinTech (novel solutions to enable easy financing and insurance) is highlighted in the report of Think Ag 2020.

Precision AgTech includes companies either exclusively software-led or coupled with IoT devices to collect data. These startups offer solutions in farm management, remote sensing, traceability, digital grading, and "Uberization" of farm services. Funding deal in 2017/2018 primarily focused on IoT and market

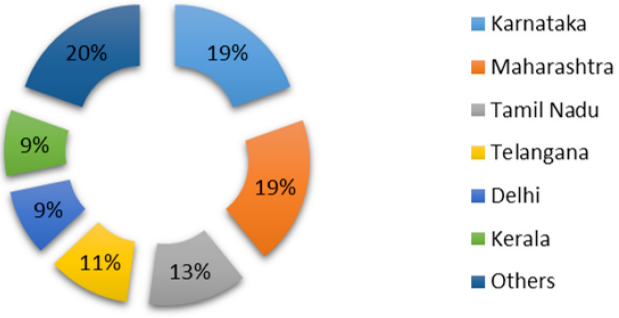

Figure 5 State-wise representation of IoT startups in agritech sector (*Source* Startup India website Accessed on 20th Feb.2020)

linkage platforms. Recently NITI Aayog has initiated a pilot project on precision agriculture using Artificial Intelligence in 10 districts from seven states. Similarly, Agri open data portals have been launched by states of Telangana, Tamil Nadu, and Maharashtra. Karnataka has collaborated with IBM for forecasting pricing of agricultural commodities using AI and ML technologies.

There are about > 1500 IoT based startups in India and out of this only 5% are in the agritech sector. The state wise data indicates that Karnataka and Maharashtra are the most prominent hubs of supporting startup ecosystem having 19% of startups in each, followed by Tamilnadu and Telangana with 13 & 11% of IoT based agri startups.(Figure 5) The aggregation of the agri startups in the southern part of India may also be partially due to the favorable policies and conducive ecosystem of the Agribusiness incubators such as aIDEA, ICAR-NAARM, Villgro, ICRISAT, C-CAMP etc. nurturing the early–stage enterprises having high growth potential.

Recently, many agritech startups holding patents have attracted investments from venture companies. Table 2 shows few such innovative startups.

Table 2 Promising IoT based Indian Agristartups holding patents

S.No.	Startup	Area	Patent No.	Investment
1.	AgNext Chandigarh	Precision farming, hyperspectral imaging	IN201931006934 IN201731027171	$21mn
2.	Stellapps Pune/Benguluru	Dairy supply chain digitization via IoT	3018/CHE/2013 3020/CHE/2013 3026/CHE/2013	$14mn
3.	Cropin Benguluru	Precision agriculture	-	$8mn
4.	Intello labs Benguluru/Gurgaon	Supply chain with AI & IoT platforms	IN201947032826	$5.9mn
5.	Fasal Gurgaon	Climate Smart Precision Agriculture	-	$1.6mn
6.	Krishitantra Udipi	IoT based device for soil testing	IN201941032268 IN201841041790	$1mn
7.	Hydrogreens Benguluru	Micro climate –controlled fodder grow house	IN201941051982	Prize grant (undisclosed)
8.	Poultrymon Hyderabad	IoT based platform for poultry	IN201841012716	$0.135
9.	SNRAS Systems Pune	Blue box- Re-circulatory aquaculture system	IN201921026336	Boot Strapped
10.	Bariflo Labs Benguluru/ Bhuvanewswar	AI & IoT Aeration device for aquaculture	IN201831031000 IN320950-001 IN320950-003	Boot Strapped

Source Indian Patent Office and others

AgNext is a precision agriculture startup working on the juncture of hardware, software, and analytics for quality estimation in food and agriculture. Accelerated by aIDEA, ICAR-NAARM and incubated at IIT Kharagpur, AgNext has raised funding from impact venture Omnivore and recently has received $21 million Series A funding from Alpha Wave Incubation. Stellapps, an IoT based dairy farm solution firm, has raised $14mn from Bill & Melinda Gates foundation and IndusAgePartners. Gurugram based startup Intello Labs provides image analysis-based solutions for agri product grading, recently raised Series A funding from Saama Capital. The agristartup Fasal uses its AI-powered IoT-SaaS platform to help the farmers. The platform captures real-time data of the crop from on-farm sensors and delivers farm-specific, crop-specific actionable advisories to farmers via mobile in vernacular languages. Fasal, got seed funding led by Omnivore Ventures and Wavemaker Partners in 2019. Krishitantra for soil testing received seed funding of Rs. 4.00 Cr. from NAB Ventures and Omnivore.

Conclusions

In last few years, Agri Startups have got a boost from the Government of India and the recent reforms announced in the agriculture are expected to revolutionize the sector. Penetration of the digital technologies such as IoT & AI, blockchain etc. has enabled many startups to venture into agriculture and receive support from investors for scaling and helping the farmers. This study provides insights about the distribution of IoT based patents in agriculture sector in India. It shows the emergence of innovative agristartups holding the IoT based patents with applications in precision agriculture, dairy, fisheries etc. From a geographical perspective, it is interesting to highlight the concentration of these startups in the states of Karnataka, Maharashtra, Tamil Nadu and Telangana having favorable startup policies.

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