Mapping Digital Agritech Innovation in India and Japan Through Patent Analytics and Startup Ecosystem Dynamics

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Abstract – Modern technologies and innovations are rapidly transforming ventures within the agricultural field. In this study, we examine patent records and agritech startups in India and Japan to identify the differences in agri-tech adoption and innovations in these two countries. Patent records on digital agriculture, IoT, robotics, geo-spatial technologies, drones, sensors, and blockchain for the years 2013-mid-2025 were provided by Questel Orbit. These patents were cleaned and categorized into 5 technology domains. We recorded agri-tech startups from Tracxn, Crunchbase, as well as country-specific records, and filtered them by year of startup, funding received, product diversity, technological focus, and market. Results show that in India, UAV sensor, data analytics, and agri-tech IoT systems are more developed compared to Japan's. However, the diffusion of geospatial technology in both countries is still in the developmental stage.

Keywords – Agritech, Digital Agriculture, Patents, Startups, Technology Adoption, India, Japan, Innovation Ecosystem.

I. INTRODUCTION

In the entire history of humanity, the field of agriculture has experienced significant growth. Flora and fauna's cultivation and domestication starting various decades ago, while systematical crop development and rotation in farming activities started some years ago. The terminology 'green revolution' featured by the strategic diversification of fertilizers and pesticides, as well as breeding of animals, started several years ago. Currently, agriculture is a significant field, which has enhanced food security. In order to sustain the growing global population amid scarce land resources and rising environmental and climatic challenges, it is important to increase both livestock and crop production [1].

Digital Agriculture (DA) depends of 5 significant controls for activities, which collectively foster creativity. These include (1) availability of data from advanced sensors, which include nano-sensors and satellites, as well as communication and storage technologies; (2) a surge in computing power enabling the implementation of artificial intelligence and novel modeling techniques; (3) connectivity and data exchange points; (4) decision support and knowledge management in agriculture; (5) robotics, control, and automation. Over the last 3 decades, agricultural practices have been advanced by wide usage of technology such as automation and control models, data analytics tools, and web-based apps [2].

The main purpose of these advancements has been to enhance the productivity of agricultural lands and resources. From 1910s up to 2010, most farmers have employed localized sensing tools, GPS and satellite imagery to enhance farm activity tracking and determine agricultural flow [3]. Intelligent farming and precision agriculture approaches have developed towards modernization considering the introduction of long-range wireless sensors, UAVs (unmanned aerial vehicles), and IoTs (internet of things) to further enhance food supply sustainability. The various elements used in intelligent farming and precision agriculture have been illustrated in **Fig. 1**.

Precision Agriculture (PA) makes use of data collected from multiple sources such as mobile sensing devices, and satellite imagery, to identify issues, enhance agricultural output through effective application of current resources. Smart agriculture employs IoT-based automations, robotics, mobile apps, and wireless models to effectively track, assess, and regulate soil conditions, weather variations, and water resources in farming fields, thus boosting efficiency and minimizing expenses [4]. The application of water loss controls, intelligent irrigation, and progressive soil nutrient monitoring levels in various areas has been boosted by wireless sensors and IoT devices in the field of automation [5].

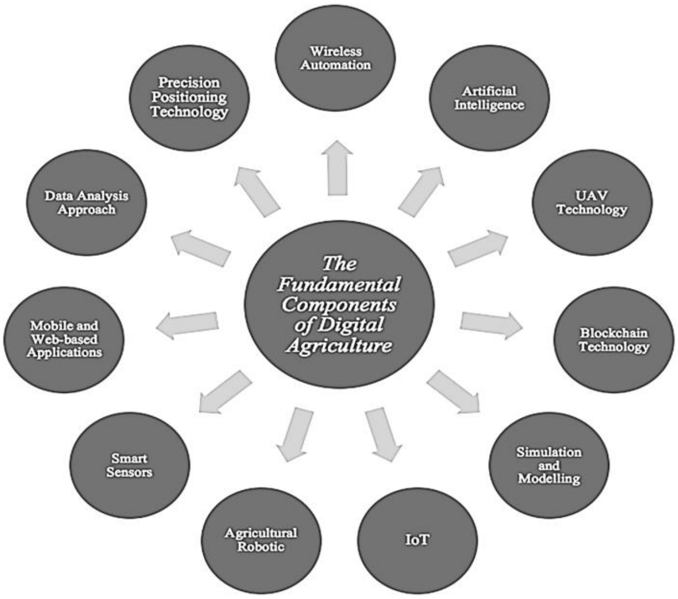

Fig 1. DA Components from Cell Phones to Blockchain.

Within the past few decades, the increasing acceptance of digital technology by agriculturalists has garnered significant attention of entrepreneurs, industrial leaders, and policymakers. Employing platform-oriented IoT for solutions across the value chain has proved to be more profitable and enhances the effective application of resources with enhanced predictability and accuracy [6]. Recent years have shown that farmers in developing countries are deploying smart farming methods. These methods, integrated with IoTs, utilizes a synergistic approach of the internet, wireless communications, and RMS (remote monitoring systems).

As a result, these advancements are able to boost the efficiency of supply chains, market strategies, and farm productivity, which enhances doubling of income and stimulates robust economic stimulus to precision agriculture under Atma Nirbhar Bharat. India is promoting private investment in agriculture. Government support and enhanced digital architecture enable agritech setups to innovate by integrating contemporary technologies such as the remote sensing, AI, data analytics, and IoT, thereby providing solutions that address the challenges faced by agriculturalists. Numerous agricultural firms are establishing their presence via proprietary technology [7].

This research is aimed at evaluating the diffusion and development of digital agricultural technologies in India and Japan through the connection of patent activity to agritech startup processes. The research intends to determine the branches of technology that are driving agritech innovations, the relative strengths and gaps between the two nations, and the way that the entrepreneurial activity, patterns of investment, and macro level policy conditions interact with evidence of technological advancements based on patents.

The remaining sections of this study have been organized as follows: Section II describes the study area and sources of data; patent data collection/classification, startup data collection and profiling; and analytics framework. Section III discusses our findings, evaluating key aspects and technologies (such as geospatial technology, geoinformatics, data analytics, IoT, and big data) in agritech firms. Section IV concludes our study and highlights how digital agronomy develops in India and Japan.

II. METHODOLOGY

Study Area and Data Sources

The research question is the following: what is the adoption rate and start-up frequency of agricultural technology in India and Japan, as countries with opposing innovation environments and degrees of digital agriculture acceptance. India is a fast-growing market with high rates of startups and the use of digital and IoT-enabled agricultural solutions. There is a more developed technology sector in Japan with slower adoption of agritech. In order to seize the technological environment, the research employs patent applications, startups, and venture capital as pointers of innovation. The data on patents were acquired through the Questel Orbit database, which is a universal database of patent applications and grants worldwide.

The information on startups, such as the year of founding, technology focus, funding, and products offered, were gathered using the Crunchbase, Tracxn and national startup registries. Trends in historical patent data were analyzed based on the data of 2013 to mid-2025 during a period of ten years. Additional background contextual data on the matters of agriculture, digital adoption, and innovation policy were received through access to national statistical agencies, FAO, and World Bank data and served as a background to explain the dynamics of technology adoption and startup [8].

Patent Data Collection and Classification

Keywords searches and International Patent Classification (IPC) codes that pertained to agricultural technologies, digital agriculture, IoT, robotics, geospatial technologies, unmanned aerial vehicles (UAVs), sensors, and blockchain applications were used to extract patent records out of Questel Orbit. Patents were also confirmed to be relevant in agricultural applications and duplicates and irrelevant entries were eliminated. The five main areas of technologies, in which patents were divided, included IoT and data analytics, robotics, blockchain, UAVs and sensors, and geospatial technologies. Appreciating the fact that several patents indicate several technologies, one patent may be registered under various categories. This classification made it possible to make cross-technology and cross-country comparisons in detail. **Fig. 2** is the data preparation flow starting with the extraction to the ultimate categorization, which shows the process of the patent data collection, cleaning, verification and categorization.

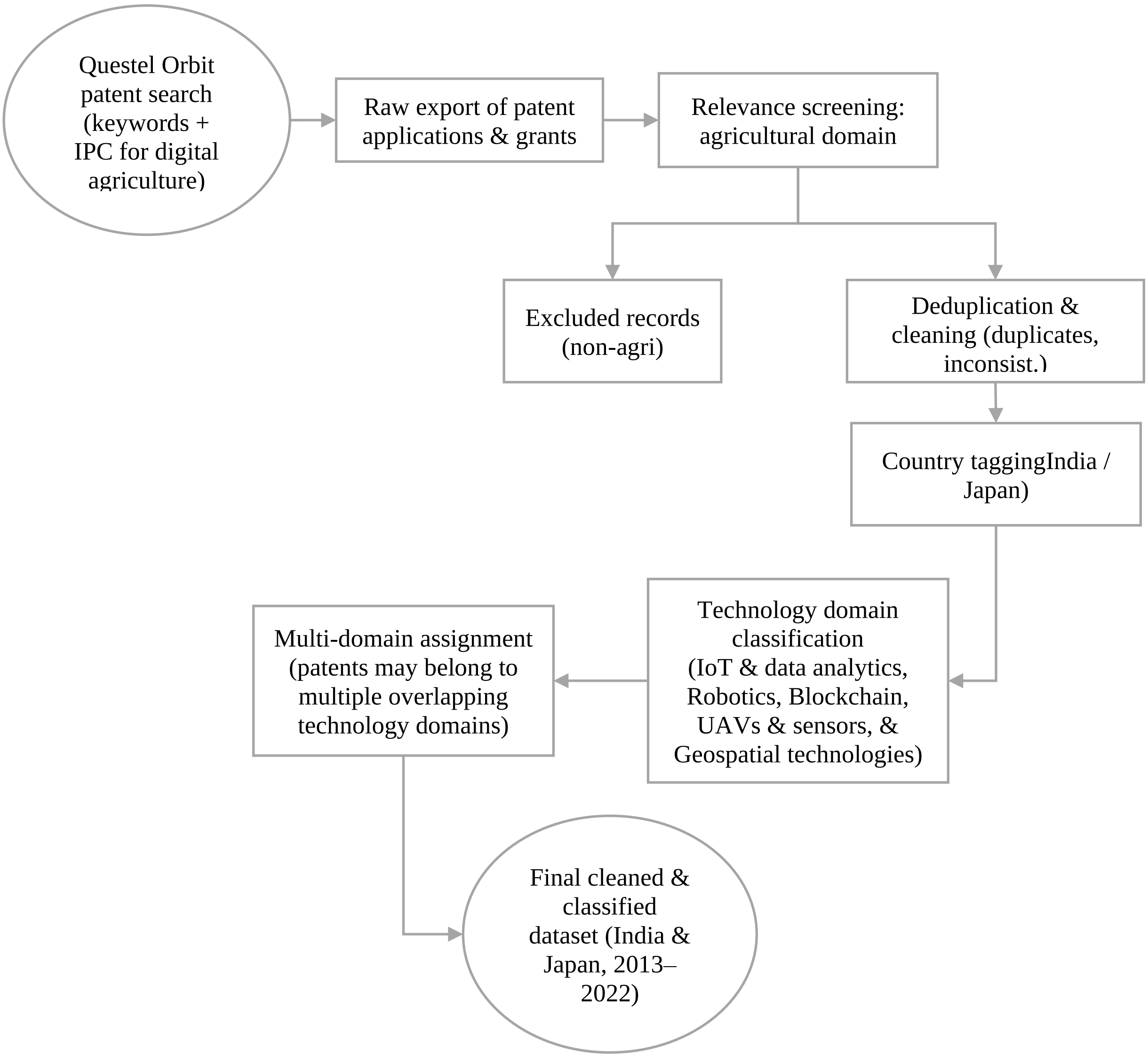

Fig 2. Flow Diagram Outlining Procedures Around Patent Data Collection, Verification, and Classifications.

Startup Data Collection and Profiling

Simultaneously, agritech startups activity was examined as an indicator of innovation spread in the study. The identification of startups was made using Crunchbase, Tracxn and national registries and the inclusion criteria were based on the focus of agricultural technology and status of operations. In the case of every startup, we gathered data about the year of foundation, amount of funds raised, specialization in technology, products provided, and market coverage. The patents to startups were integrated to group them based on the same technology areas [9]. Especially close consideration was paid to start-ups that combine various technologies, like UAV-based surveillance with IoT sensors, which represent high-impact technologies that can enhance the productivity and viability of agriculture. Based on this profiling, a critical assessment of entrepreneurial activities in boosting technological innovations based on patents could be achieved.

Analytical Framework

The assessment employed trend visualization, comparative analysis, and descriptive statistics to assess technological adoption. Trends in patent filing and granting were calculated on a yearly basis per country as well as relative to each domain of technology. Comparative analysis evaluated the differences between India and Japan, with the prominent and emerging technologies. The adoption of cross-technology was investigated by finding out patents that were grouped in different categories, which indicated the convergence of technology. Visual representation was done using time-series charts that represented annual trends of patents (see **Fig. 3**) and comparative bar charts that represented distribution by technology domains (see **Fig. 4**).

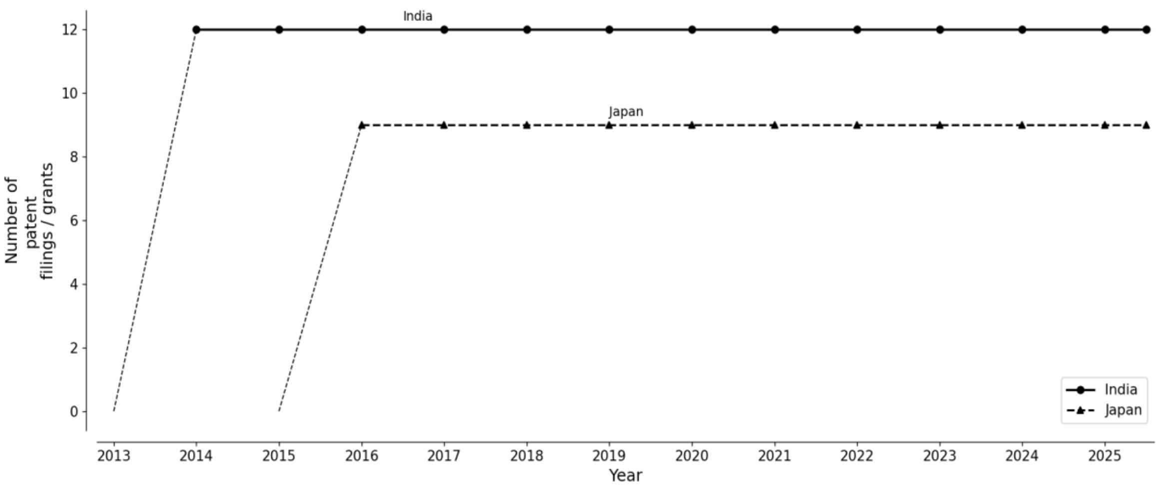

Fig 3. India and Japan Annual Trend of Patent Applications and Registrations in the Years 2013- Mid-2025.

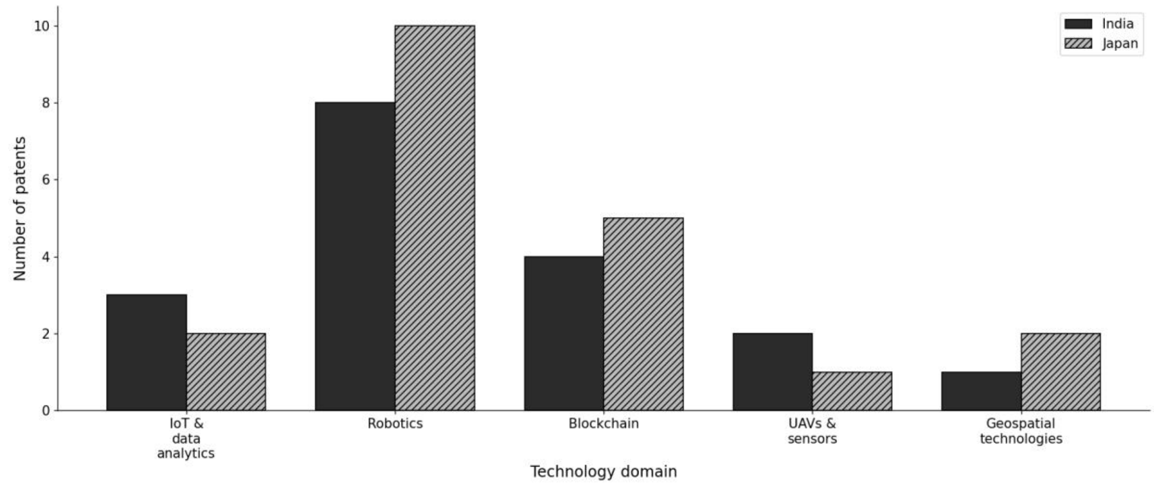

Fig 4. Comparative Analysis of The Distribution of Patents Across Various Tech Domains in India and Japan.

In order to incorporate the activity of startups, the correlation between the number of startups, filings of patents, and investments was analyzed. The analytical framework further taken into consideration the macroeconomic and policy factors affecting the technology uptake which included national innovation policy, market demand of accuracy agriculture and the incentive of sustainability. The relationship between patent analysis, startup profiling, and general technology adoption can be characterized by a conceptual flow diagram (see **Fig. 5**) that illustrates how patents and entrepreneurial activity both contribute to the organization of the dynamics of agritech innovation knowledge.

III. RESULTS AND DISCUSSION

Agritech firms that use big data and IoT signify more control over agricultural monitoring and automation. This therefore leads to increased agricultural output and presents an opportunity for continuous development. Agritech firms has the power not only to enhance crop output but also to address economic, social, and environmental challenges, hence fostering productivity development within the agricultural sector. Patent trends show sustained and progressive development in agri-tech sector over the past few years with approximately 24,353 innovations being recorded. China was a leader in the competition with 70% of patent application, while India was third with 4%. Japan recorded a 1% patent filing during this competition (see **Fig. 6** and **Fig. 7**).

This competitive analysis shows that the contribution of India to IoTs and data analytics is significant. On the contrary, Japan demonstrated less involvement in employing robotics, blockchain, and data analytics to boost its agricultural practices. Japan and India are collaboratively involved in the field of wireless sensors and aerial vehicles, with India recorded for 3/4 of overall fillings between two countries. Geoinformatics and geospatial technologies are fundamental in various fields, such as environmental planning, emergency planning, agriculture, resource oversight, and urban planning [10].

Technologies such as remote sensing, GPS, and GIS facilitate the recording, analysis, and presentation of geographical data [11]. They facilitate the integration of diverse sources of data, such as aerial images, field surveys, and satellite images, to produce accurate/real-time spatial models and maps [12]. Geoinformatics is fundamental in precision agriculture since it enhances sustainability and production.

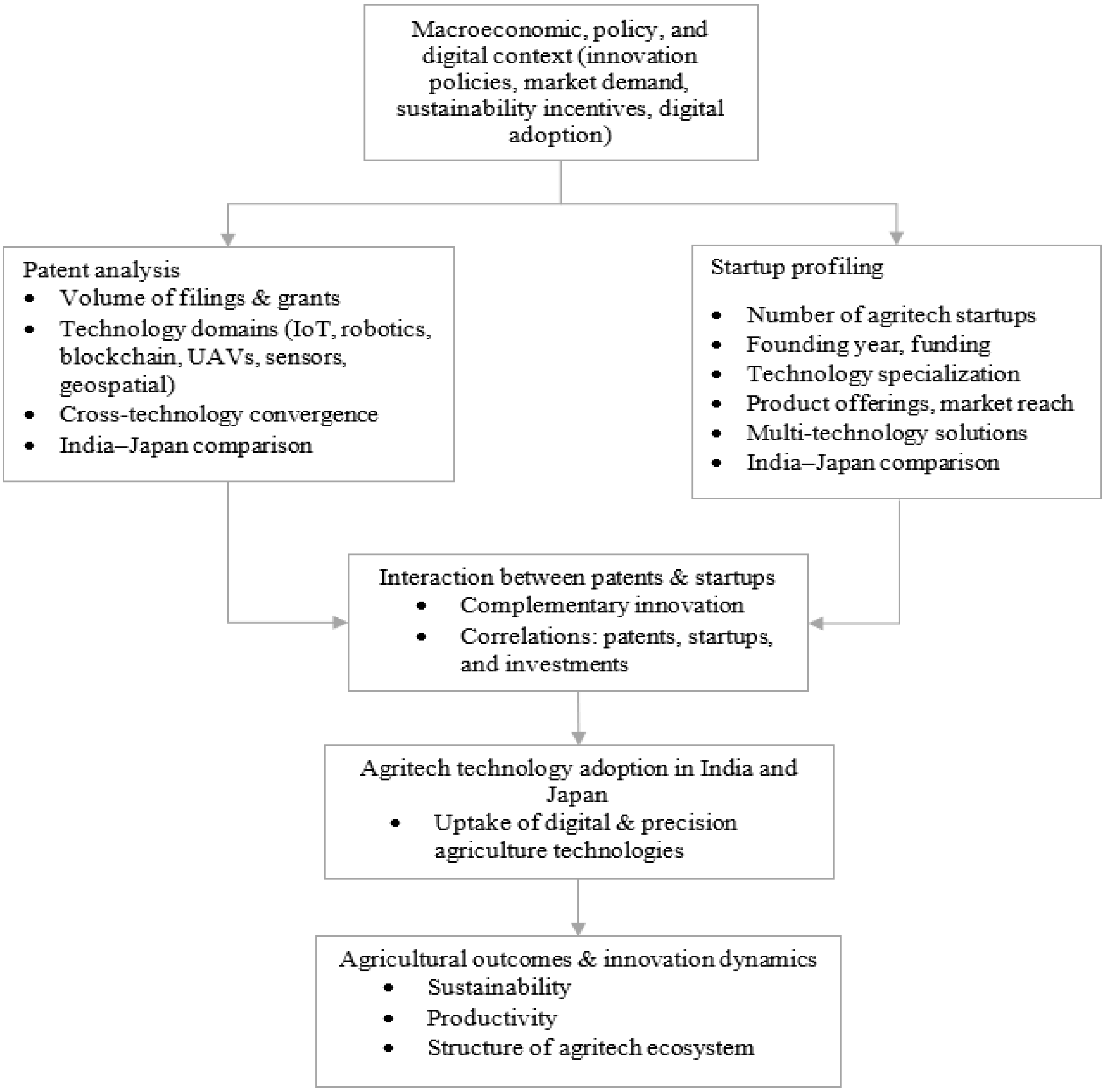

Fig 5. Outline The Relationships Connecting Patent Analysis, Startup Profiling, and the Adoption of Technology.

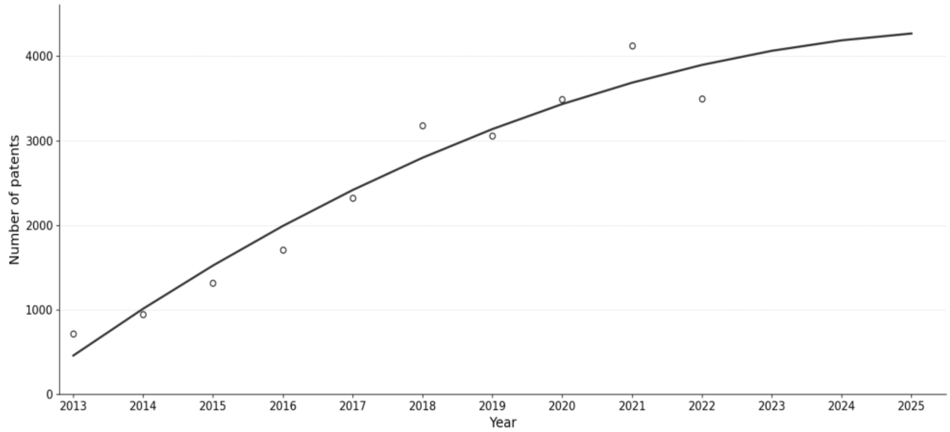

Fig 6. Trend in Patenting.

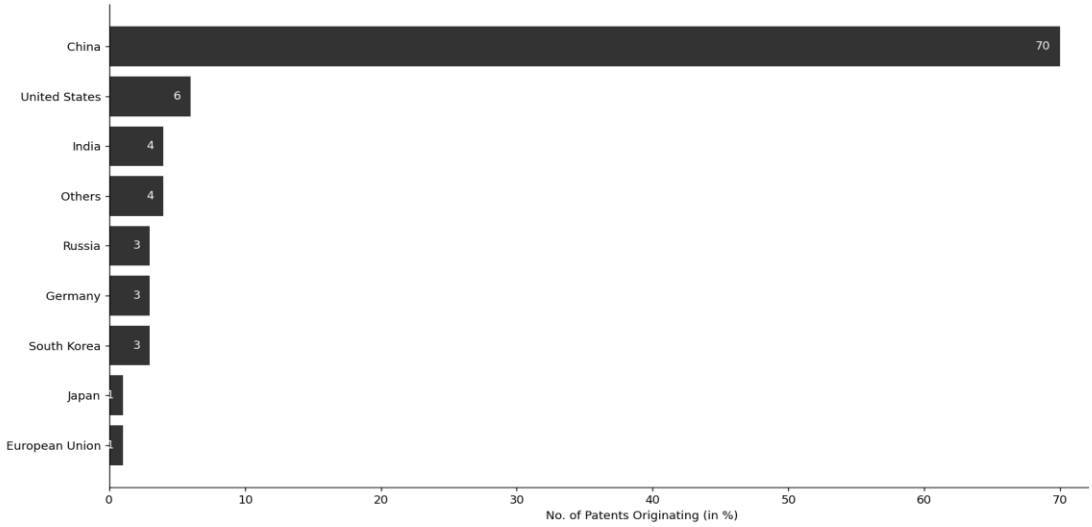

Fig 7. Publication Patterns of Applied- and Approve-for Patents (Records From 2013 to Mid-2025).

Most precision farmers may employ geospatial technology to evaluate edaphic factors, identify optimal locations of farming production, oversea irrigation systems and fertilizer control, and predict crop diseases and insect infestation. By using this technology, farmers can make informed decisions concerning planting methods, crop selection, and distribution of resources.

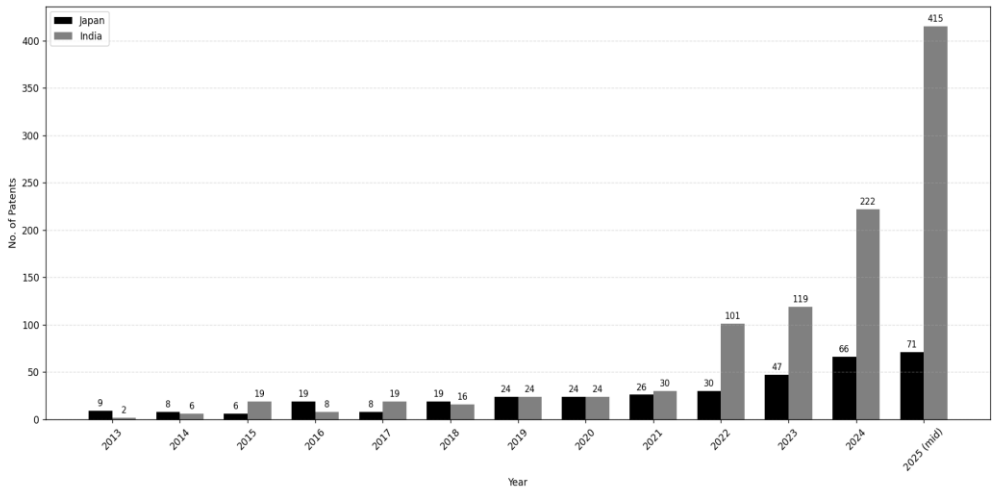

Fig 8. India and Japan's Patent Application and Grant Trends (2013–Mid-2025).

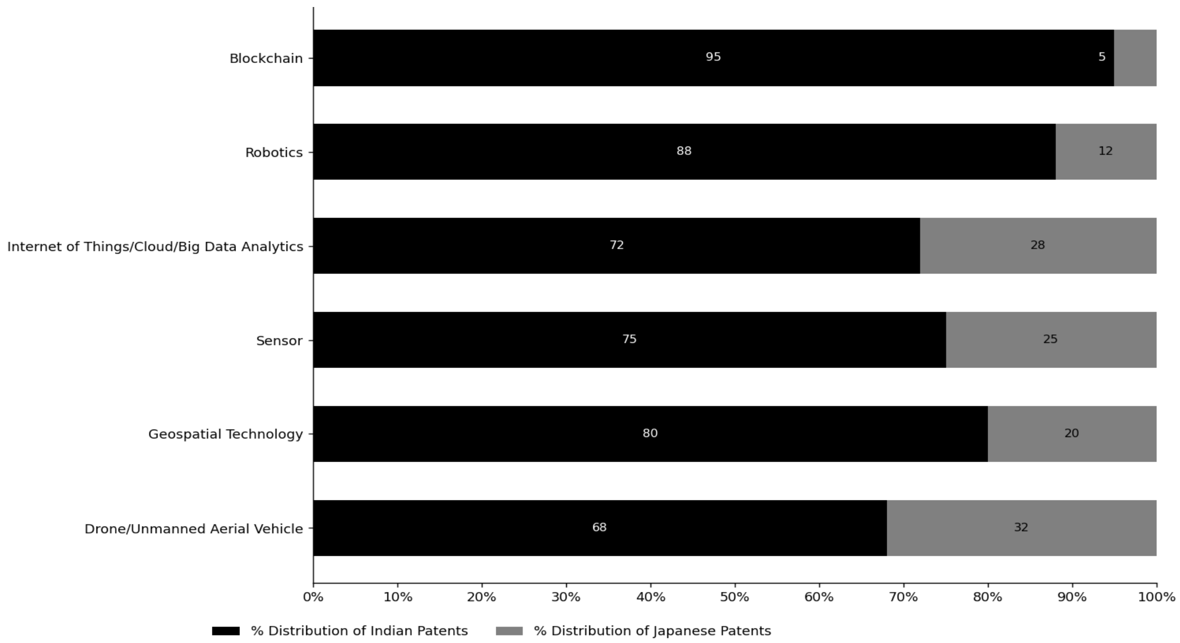

Fig 9. Comparative Patent Examination of Different Agricultural Technology from Japan and India.

In addition, geospatial technology stimulates the application precision farming approaches, such as variable rate usage, and site-centric controls, which are vital in mitigating ecological effects and boosting resource efficiency [13]. Geoinformatics and satellite imagery provide critical instruments useful for data analysis, administration, and decision-making across various agricultural fields. The need of precise weather predictions in today's quickly evolving environment is paramount. Geospatial technology for agricultural applications is an emerging phenomenon, and both nations have started exploration in this domain (see **Fig. 8** and **Fig. 9**).

Due to overlapping technologies and the application of numerous technologies by inventors to address problems, a single patent is divided into many categories. Global trends influencing the use of agricultural technology include consumer emphasis on sustainability, changing business models, regulatory frameworks, and macroeconomic factors. The agricultural food tech business has seen significant expansion. In 2021, the agricultural food technology sector garnered USD 18.2 billion, reflecting a 38% annual growth rate since 2013. These serve as push factors for the rising trend of agritech firms. The quantity of farmers encountering agritech firms has also increased.

Disruptive innovation may result in the reorganization of the agricultural value-creation process. Khan and Arif [14] identified significant pathways of disruptive innovation in agriculture. Nevertheless, several absent tendencies and deficiencies were identified in current DI research within agriculture, perhaps motivating scientists to further investigate the agricultural setting. The authors identified trends to address deficiencies in the current agricultural DI literature, which will enhance industry efficiency. **Table 1** delineates the study examined within the chosen issue and outlines a prospective research agenda predicated on 7 research gap categories that future studies may address.

Table 1. A Roadmap Outlining the Direction of Future Agriculture DI Research [15]

SN.	Research Gap Types	Study Areas	Future Study Agendas
1.	**Evidence**	The majority of the studies focused on: • Industrialized nations. • Focus on technology (e.g., digital strategy, security, AI, etc.) • Supply chain for food. • Chain of supply and value in agriculture	There is a wealth of literature on: • Low-income nations and transition economies • All links in the fishing, forestry, and cattle supply chain. • The size of the farm.
2.	**Knowledge**	Expanded understanding of mass, low-end, and specialty food markets; agricultural systems and technology; the evolution of DI theory; agricultural education; the food value chains; and extension	How can a market or industry overcome the difficulty of deploying DI? A number of sub-industries based on production have yet to be investigated. The evolution of agricultural education curriculum

SN.	Research Gap Types	Study Areas	Future Study Agendas
3.	**Practical knowledge**	Enhanced familiarity with certain business processes and industries at the micro and macro levels Agricultural worth Value of food Tea Rice Agriculture education etc.	This area of the agricultural market needs more research. It has to grow the agricultural business by exploring sub-sectors such as poultry, nursery, fishery, and dairy, for instance.
4.	**Methodology**	Using a Quantitative-Qualitative Literature Review, researchers An Overview of Systematic Literature Review	The majority of the studies used qualitative methods such as case studies, interviews, observations, grounding theory, etc., and were mostly exploratory in nature.
5.	**Empirical**	A small amount of literature was reviewed that focused on practical skills; the themes were identified from this literature review.	To back up the hypotheses put out regarding DI and DT, a little amount of study was carried out.
6.	**Theoretical**	AgriTech, food value chain, sustainable DI and other areas of theoretical knowledge have been the focus of further investigation.	The agricultural industry's sub-sectors and their supply chain operations have, however, received little attention from empirical and theoretical researchers.
7.	**Population**	The majority of empirical studies focused on certain demographics, such as age, occupational status, subculture, etc.	No study on census sampling has been conducted.

The principal focuses of DI research in agriculture included food value chains, high-end, mainstream, and low-end markets; theoretical progress in DI; agricultural education; and agricultural technology and systems [16]. Numerous production-oriented sub-industries remain unexamined about strategies to address the complexities of implementing Digital Innovation for a market or sector. Furthermore, while DI possesses a comprehensive understanding of the agricultural value chain, agricultural education, tea, rice, and food value chains at both macro and micro levels, their knowledge of the sub-sector of the business is minimal, if not nonexistent [17]. To advance the agricultural sector, it is essential to examine sub-sectors such fisheries, nurseries, poultry, and dairy. The authors assert that future research by the DI and agricultural scalars should include these pathways to enhance the significance of information in agricultural literature.

IV. CONCLUSION

The agritech patents and startup activities report demonstrate how digital agronomy alters and grows in an intermittent flow across India and Japan. During the period in question, an impressive volume of agritech innovations emerged. India and Japan, as innovators from the global south, had a much smaller but still significant contribution as China dominated the patenting. India had more IoT and data analytics, and sensor-mated UAV applications, while Japan was more reserved in her data-heavy, robotics and blockchain-based agritech. In geospatial technologies for agricultural applications, both countries have just started and are still in the emerging space. The agritech startup ecosystem has expanded with the flow of global investments in agricultural food technologies, demonstrating the importance of these young firms in bridging patenting and value systems with innovation.

CRediT Author Statement

The authors confirm contribution to the paper as follows:
Conceptualization: Hiroshi Miyano and Anandakumar Haldorai; **Methodology:** Anandakumar Haldorai; **Data Curation:** Hiroshi Miyano; **Writing- Original Draft Preparation:** Hiroshi Miyano and Anandakumar Haldorai**; Investigation:** Hiroshi Miyano; **Supervision:** Anandakumar Haldorai; **Validation:** Hiroshi Miyano and Anandakumar Haldorai; **Writing- Reviewing and Editing:** Hiroshi Miyano and Anandakumar Haldorai; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests

There are no competing interests

References

[1]. T. U. Rahman, S. Shah, S. Hassan, and S. Fahad, "Food security challenges and adaptation strategies in china amidst global climate change," Journal of Umm Al-Qura University for Applied Sciences, Apr. 2025, doi: 10.1007/s43994-025-00226-5.
[2]. G. Gebresenbet et al., "A concept for application of integrated digital technologies to enhance future smart agricultural systems," Smart Agricultural Technology, vol. 5, p. 100255, May 2023, doi: 10.1016/j.atech.2023.100255.
[3]. P. Radoglou-Grammatikis, P. Sarigiannidis, T. Lagkas, and I. Moscholios, "A compilation of UAV applications for precision agriculture," Computer Networks, vol. 172, p. 107148, Feb. 2020, doi: 10.1016/j.comnet.2020.107148.
[4]. M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour, and E.-H. M. Aggoune, "Internet-of-Things (IoT)-Based Smart Agriculture: Toward making the fields talk," IEEE Access, vol. 7, pp. 129551–129583, Jan. 2019, doi: 10.1109/access.2019.2932609.
[5]. S. Touil, A. Richa, M. Fizir, J. E. A. García, and A. F. S. Gómez, "A review on smart irrigation management strategies and their effect on water savings and crop yield," Irrigation and Drainage, vol. 71, no. 5, pp. 1396–1416, Jun. 2022, doi: 10.1002/ird.2735.
[6]. T. K. Raj and S. D. Gowda, "Review on Agricultural Supply Chain: Predicting Agricultural product demand and Quality through Integration," in Lecture notes in electrical engineering, 2025, pp. 459–480. doi: 10.1007/978-981-96-0165-3_33.
[7]. S. Rotz et al., "The Politics of Digital Agricultural Technologies: A Preliminary review," Sociologia Ruralis, vol. 59, no. 2, pp. 203–229, Feb. 2019, doi: 10.1111/soru.12233.
[8]. K. S. Alexander et al., "What is technology adoption? Exploring the agricultural research value chain for smallholder farmers in Lao PDR," Agriculture and Human Values, vol. 37, no. 1, pp. 17–32, Jun. 2019, doi: 10.1007/s10460-019-09957-8.
[9]. F. Michelino, A. Cammarano, E. Lamberti, and M. Caputo, "Open innovation for start-ups," European Journal of Innovation Management, vol. 20, no. 1, pp. 112–134, Dec. 2016, doi: 10.1108/ejim-10-2015-0103.
[10]. J. C. Nagavi, B. K. Shukla, A. Bhati, A. Rai, and S. Verma, "Harnessing Geospatial Technology for Sustainable Development: A Multifaceted Analysis of Current Practices and Future Prospects," in Sustainable Development and Geospatial Technology, 2024, pp. 147–170. doi: 10.1007/978-3-031-65683-5_8.
[11]. Y. Xue, A. P. Cracknell, and H. D. Guo, "Telegeoprocessing: The integration of remote sensing, Geographic Information System (GIS), Global Positioning System (GPS) and telecommunication," International Journal of Remote Sensing, vol. 23, no. 9, pp. 1851–1893, Jan. 2002, doi: 10.1080/01431160110069953.
[12]. T. K. Gottschalk, F. Huettmann, and M. Ehlers, "Review article: Thirty years of analysing and modelling avian habitat relationships using satellite imagery data: a review," International Journal of Remote Sensing, vol. 26, no. 12, pp. 2631–2656, Jun. 2005, doi: 10.1080/01431160512331338041.
[13]. D. P. Roberts, N. M. Short, J. Sill, D. K. Lakshman, X. Hu, and M. Buser, "Precision agriculture and geospatial techniques for sustainable disease control," Indian Phytopathology, vol. 74, no. 2, pp. 287–305, Feb. 2021, doi: 10.1007/s42360-021-00334-2.
[14]. Md. R. Khan and Md. Z. U. Arif, "Systematic review of disruptive innovation (DI) research in agriculture and future direction of research," Telematics and Informatics Reports, vol. 11, p. 100079, Jul. 2023, doi: 10.1016/j.teler.2023.100079.
[15]. E. D. Farsani, S. Choobchian, and M. S. Naghani, "Unlocking Agricultural Innovation: A Roadmap for growth and Sustainability," Journal of the Knowledge Economy, vol. 15, no. 4, pp. 17751–17771, Feb. 2024, doi: 10.1007/s13132-024-01860-w.
[16]. Md. R. Khan, H. G. Rammal, and Md. Z. U. Arif, "How do disruptive innovation (DI) interventions impact diverse business and technological model innovations: An umbrella review," FIIB Business Review, Jul. 2025, doi: 10.1177/23197145251356368.
[17]. A. Devaux, M. Torero, J. Donovan, and D. Horton, "Agricultural innovation and inclusive value-chain development: a review," Journal of Agribusiness in Developing and Emerging Economies, vol. 8, no. 1, pp. 99–123, Feb. 2018, doi: 10.1108/jadee-06-2017-0065.

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