

REVIEW PAPER

Digital Agriculture using advanced ICT and Agricultural Information Systems- *The general and financial aspects in Indian Context*

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ABSTRACT

Agricultural Informatics is a modern and interdisciplinary field of practice and study. It has incorporated from the information technologies, basic technologies and various aspects of agriculture, and horticulture. Agricultural Informatics sometimes referred as ICT in Agriculture, Agricultural Information Systems, Agro Information Technology, etc. It is dedicated in transforming agriculture sector supported by information driven systems which are supported by ICT). Agro Informatics is responsible in delivering as well as accessing information. The applications in Agro Informatics in agriculture enhancing agriculture production, nationally and internationally and as a result new practicing concepts been developed called Digital Agriculture and Smart Agriculture. In addition to basic Information Technologies Agricultural Informatics is also supported by different other emerging sub components such as Big Data, Data Analytics, Cloud and Virtualization, Internet of Things, Wireless network with Converged Network, Usability and HCI, UXD, Sensor and Multimedia Systems. Different economical and financial issues are alarming and growing internationally in respect of Agriculture and environment. A proper Agro Informatics practices can lead the development a healthy and sophisticated agricultural systems, and proper applications helps in reaching the status of Digital Agriculture and Smart Farming supported by government, administration, universities, agricultural institutes and associations. This paper highlights the basics of Agro Informatics and Financial aspects related to the Smart Agriculture in Indian context. As a review based work existing works compiled and reported here.

HIGHLIGHTS

- ① Modern farming technology and systems are widely emerging and growing fast for developing smart agricultural systems. Such latest systems and technologies are dedicated in advancing smart decision support systems.
- ② Apart from basic technologies various latest sub-technologies are important and valuable in advancing agricultural systems including cloud computing, big-data analytics, internet of things, data science, edge computing and fog computing, etc.
- ③ According to a market study it has noted that it was predicted that in our country all type of grains about 275 MT in the year 2017 to 2028. This is worthy to note that India is ranked 2nd (top) producer of the food, and this target would be fruitful in Digital Agricultural Development.
- ④ In India different agricultural projects related to the economies and finance have been described and mentioned.

Keywords: Agricultural Systems, ICT, Computing, Smart Agriculture, Digital Agriculture, Agricultural Information Systems, Digital Economy, India

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Computing, ICT and allied Technology is important and crucial for proper development of agricultural systems in which different devices like mobile, computers, network devices are widely used. With advent of ICT in agriculture it helps in exchange of proper data and knowledge to the required or targeted audience. Wide spectrum of ICT based technologies including latest communication systems, multimedia based systems, mobile phones, e-gadgets, sensors, GPS and GIS, satellite systems, etc. (Abbasi, A. Z., Islam, N. & Shaikh, Z.A. 2014) are widely applicable and emerging in advancing each and every field and also in agricultural spectrum. Modern farming technology and systems are widely emerging and growing fast for developing smart agricultural systems (Adão, T. *et al.* 2017). Such latest systems and technologies are dedicated in advancing smart decision support systems. With support of core ICT and Computing agriculture systems different data possible to gather and manage which include weather, agriculture, managing crop quality and quantity. ICT based system enhancing different segments including governance, business, healthcare, tourism, education, industries, etc. and in this regard applications of ICT in agriculture and allied sectors are important and impactful. It

is an important fact that worldwide about sixty percentage of population uses internet and they use various channel and systems for different internet based services. ICT based systems helps and improving healthy and effective communication for transparent and instant communication. Agricultural Informatics is considered as important interdisciplinary field, and dedicated in proper smart and digital agricultural development by its different agricultural technologies, refer Fig. 1 (Paul, P.K. & S.K. Jena, 2023).

The field which is dedicated in agricultural systems and sector development using ICT is called Agricultural Information Technology or Agro Informatics which is dedicated in healthy and advanced agricultural practice (Hilbert, Martin, 2016; Holster, H.C. *et al.* 2012). This is required in developing and managing the scenario of food security, global agricultural management and trade, agro and environmental technological systems, agro and ecological management (Goraya, M.S. & Kaur, H., 2015; Guardo, E. *et al.* 2018). Strategically this field is required in diverse fields and areas for strengthening effective and proper agricultural development and management.

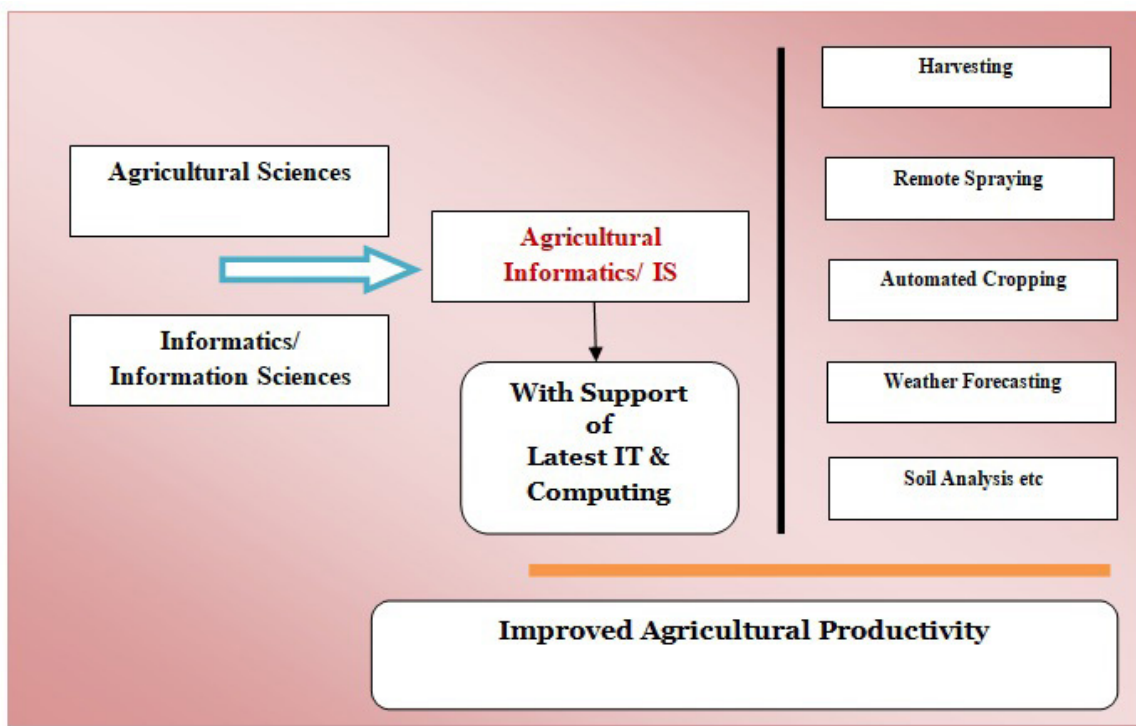


Fig. 1: Agro Informatics how supported by the technologies and it results development in agricultural systems

- ♦ Findout, enhance and also the input of Agricultural systems.
- ♦ Agricultural systems for enhancing Output systems (Kajol, R. & Akshay, K.K. 2018).
- ♦ Integrating various sub-facilities of the agricultural systems.
- ♦ In developing and managing effective Agro Business management.
- ♦ Enhancing agro pre and Post Production.
- ♦ In effective and smooth Transportation of agro products (Kamble, S.S. *et al.* 2020).
- ♦ In enhancing and modernizing the security systems of the food and agriculture.
- ♦ In effective and modern in environmental and agricultural Systems.
- ♦ In enhancing and developing value-chain development in agriculture.
- ♦ In developing proper climate data gathering and management (Khattab, A. *et al.* 2016).

Objective of the work

The work entitled “Digital Agriculture using advanced ICT and Agricultural Information Systems- *The general and financial aspects in Indian Context*” is dedicated in finding the basic and futuristic concern in Digital and Sustainable Agricultural Systems such as—

- ♦ To know about the basic concept, features and characteristics of Agro ICT and Agricultural Informatics practices.
- ♦ To gather and analyze about the Digital Agriculture and Smart Agricultural systems including its impact in agricultural systems.
- ♦ To get the data regarding financial and economical matters related to the agricultural systems in Indian context.
- ♦ To find-out the present and future scenario regarding smart and digital agricultural systems with reference to the issues in Indian scenario.
- ♦ To identify and analyze the existing and future potentialities in smart and digital agricultural with possible future remedies in brief.

Methodology Adopted

“Digital Agriculture using advanced ICT and Agricultural Information Systems- *The general and financial aspects in Indian Context*” regarding this work, this is purely a fundamental and conceptual work and identified and prepared based on existing works. As far as existing sources and study material is concerned previous journal papers, book chapters and reference books have been consulted for learning previous status and future status in brief. Existing policy works, policy papers and case studies also studied and analyzed and prepared while preparing this work. Different market survey websites, webportals also studied, analyzed and reported in this work.

Digital Agriculture: The Impact of ICT in Agriculture

The advancement of Computing and Digital technologies changing the global agricultural arena and transforming advanced agricultural systems with proper sustainability supported by harvesting, distributing agricultural marketing, etc (Liu, S. *et al.* 2019; Manos, B. *et al.* 2011). The information technology application in agricultural segment has been lead the concept of e-agriculture, smart agriculture, digital agriculture, etc (Gómez-Chabla *et al.* 2019). The integration of existing and future technologies into the agricultural systems is changing the shape and face of smarter agricultural systems and rural development perfectly. New and innovative ICT and information management systems are impactful and needed in developing effective and advanced agricultural systems and its economies (Milovanović, S. 2014). The ICT in agricultural system has many challenges and issues with agrarian economics perspective, and such challenges and issues can be overcome using sophisticated information technologies for different activities includes aspects related to the temperature, sensors, robotics and GPS technology (Gill, S.S. Chana, I. & Buyya, R. 2017). Various digital technological support in agricultural systems including drone management i.e. images of aerial images, etc (Babu, S.M., Lakshmi, A.J. & Rao, B.T. 2015). ICT has excellent impact for developing and leading the concept of digital farming which helps in modernizing and advancing agricultural systems.

Advancing and modernizing ICT in agriculture and allied areas leads effective, transparent and proper agricultural marketing and production apart from pre-agricultural activities. Various latest components of Information Technology such as web-systems, networking systems, database systems, multimedia systems, and obviously software systems impactful in advancing agricultural development and production (Ahmad, T., Ahmad, S. & Jamshed, M. 2015). Apart from basic technologies various latest sub-technologies are important and valuable in advancing agricultural systems including cloud computing, big-data analytics, internet of things, data science, edge computing and fog computing, etc (Adetunji, K.E. & Joseph, M.K. 2018). Latest sensing technologies are impactful and required for data gathering using various tools such as drones, soil analyzing devices for collecting soil health, soil weather conditions. Identification of natural resources, environmental condition, advancing precision agriculture is positively possible with precision agricultural systems for greater agro systems development and cost reductions (Channe, H., Kothari, S. & Kadam, D. 2015). As far as decision making tools are concerned agro informatics are impactful and need of the hour (Bauckhage, C. & Kersting, K. 2013).

Digital Agriculture, Financial Concern and India

The Information Technology and Computing applications reveals many new age and state of the art technologies including Cloud Computing, Internet of Things, AI and DL, Robotics and Intelligent Systems, sensors, networking systems, etc (Balamurugan, S. *et al.* 2016). As per study it has noted that it was predicted that in our country all type of grains about 275 MT in the year 2017 to 2028. This is worthy to note that India is ranked 2nd (top) producer of the food. And this is according to the Nation's leading body Food and Agricultural Organizations (FAO). As far as production of pulses are concerned country considered as first with about 25 % of total output, and as far as consumer of pulses are concerned it is 27%.

As far as some of the crops like paddy, whet, etc. India considered as leading in the world. Regarding Agricultural Systems it is considered as biggest in the world comprises with many Agricultural

government bodies, ministries of the union and the states, associations and foundations, agricultural universities etc (Paul, P.K. 2023). And among the leading name in this context important are ICAR i.e. Indian Council of Agricultural Research, NARS i.e. National Agricultural Research System (NARS), Central Food Technological Research Institute (CFTRI), Central Rice Research Institute (CRRI), Indian Institute of Pulse Research (IIPR), etc. According to a statistics of 2019, about 42% of labour force was used in Agriculture and allied sector itself, and it has contributed 19.9 % of the GDP or Gross Domestic Product and this is dedicated and ensuring food security of 1.3 Billion of population, and therefore use of computing and technology may be considered as one of the important driving force in developing and advancing agricultural systems with a proper digital agriculture and smart agricultural systems (Paul, P.K. 2021a; Paul, P.K. 2021b).

he digitalization of agriculture must be supported by the ICT and specially latest technologies like Artificial Intelligence and as per NITI Ayog the rate of expanding may be 4% for keeing the annual growth of eight to ten percent. Further this commission also predicts in its report that AI and ML utilizations in with 2025 may be worth of 2.6 billion US dollar and this is simply the enhancement of 22.5% CAGR (Compound Annual Growth Rate). In addition to this, AI is also helpful to the cultivators for the enhancement of the agricultural products and crops, enhancing the amount of hybrid seeds, effective and resource-efficient farming techniques and its development (Paul *et al.* 2014). The application of AI including allied technologies is no-doubt worthy and impactful in higher productivity and accuracy in farming systems (Paul, P.K. *et al.* 2015). There are various steps taken by the Government of India and respective state government, private-public initiative for enhancing agricultural productions and scenario, and among the latest and important initiatives some of them are mentioned as follows (Cropin, 2022; Invest India, 2022) –

- ♦ In 2021 an ICT support mission related to the agriculture sector was launched by the Union Mninster of Agriculture and Farmer Welfare Mr. Narendra Singh Tomar and a leading steps various MoUs was established which including

the leading organizations such as Cisco, Jio Platform Limited, ITC Limited, Ninjacart, National Commodity and Derivatives Exchange (NCDEX), etc. This mission based on latest emerging technologies of IT and Computing and not only AI but also with blockchain, remote sensing and systems, machine learning, etc. The targeted phase of this mission is 2021 to 2025.

- ♦ In India there are more than 1000 agri-tech organizations including start-ups. All such organizations and start-ups are getting various financial support from different bodies and organizations. These start-ups are important and valuable in developing advanced ICT based agricultural systems, and smart agriculture.
- ♦ NITI Aayog has started a mission with IBM regarding getting real-time data by AI and ML for the enhancement of the crop production forecast systems. And all these tools and technologies are supportive to the soil quality, agricultural input quality control and also production enhancement with finding diseases.
- ♦ Another important technology has been developed by leading network infrastructure giant CISCO called 'ADI' or Agricultural Digital Infrastructure, and it is required for improving cultivation and exchange of knowledge and ultimate development of agriculture.
- ♦ Another leading company Jio also developed another platform known as Jio Agri or Jio Krishi and dedicated in development of proper digital eco-systems of the agriculture. It has uses AI based algorithms and dedicated in individual advices and lesions to the farmers. This app was developed in the year 2020 and frequently updated with various advancement.
- ♦ Climate changing is an alarming worldwide issue and India is not an exception on this context, and regarding this different climate smart farming methods are widely using in order to perform with sustainable ecology, cutting-edge green house gas, solar productivity and electricity systems (Aubert, B.A., Schroeder, A. & Grimaudo, J. 2012). In Gujarat Dhundi village project has been initiated for better and healthy irrigation systems.

- ♦ Unified Farmers Services Interface is a program developed by the leading Microsoft and Government of India to support small holder farmers and this is particularly required in price management and also better data generation using AI based sensors.
- ♦ Another program named SENSAGRI has been initiated by six institutions, and here drone are effective in utilized for proper land mapping and observations, therefore it is impactful in getting required data for the cultivators and helps in smart farming practices.
- ♦ Individual level initiative has been started and here name of the Pradhan Mantri (PM) *Kisan Samman Nidhi* Initiative is important where 26.4 billion dollar invested for the farmers and with this they can utilized their fund in purchasing of tool, and technologies Here agricultural technological start-ups are using AI based sensors and technologies for further processing and management.

Digital Agricultural Systems, Steps, Policies in Economic perspective

Indian agricultural system is developing very fast and for this various applications, and implications of new rules, guidelines, framework is important and required and all these subsequently applied in different context (Muangprathub, J. 2019; Na, A. & Isaac, W. 2016). The collaboration with central government with state government, state government with other regional territories, public-private partnership considered as impactful and worthy deal (Paul P.K. *et al.* 2019). Dynamic structure of the agricultural systems considered as valuable for sustainable goal and development, Indian government taking various steps and policies in developing agricultural systems including initiation, enhancing and replacing more new ICT based agricultural systems (Ozdogan, B., Gacar, A. & Aktas, H. 2017). Multi-stakeholder strategy in different context been implemented in digital agricultural systems for proper agricultural supported systems. According to a data of Mckinsey Global Institute within 2023 a value of 95 billion to be touch in agricultural systems for the technology purpose and this may include the following (Ministry of Agriculture & Farmers Welfare, PIB (2023)—

- ♦ Farmer financing through digital technologies
- ♦ Digital marketplaces
- ♦ Precision advisory

Here Fig. 2 is showing the aspects of Digitalization of agriculture which is predicted touch within 2023.

In addition to previously mentioned initiatives, various other steps and policies have been taken by respective government and agencies, herewith few brief detailing on this.

Digitalization with FPO

There are variety of FPOs i.e. Farmer-producer organizations established and it has estimated to established 10k FPOs in coming years. All these FPOs are helpful in farmer base development and agricultural technological companies are helpful in developing new age, short, and family based business development on agro field.

Initiation of Agristack

Depending upon the need of the farmers and their land a proper and effective database has been developed and agricultural technology company has been created various type of services and facilities to the cultivators (Rezník, T. *et al.* 2015). Such organizations can easily identified need of the cultivator depending upon the need of land size, crop sown, and soil conditions.

Smart soil-health cards

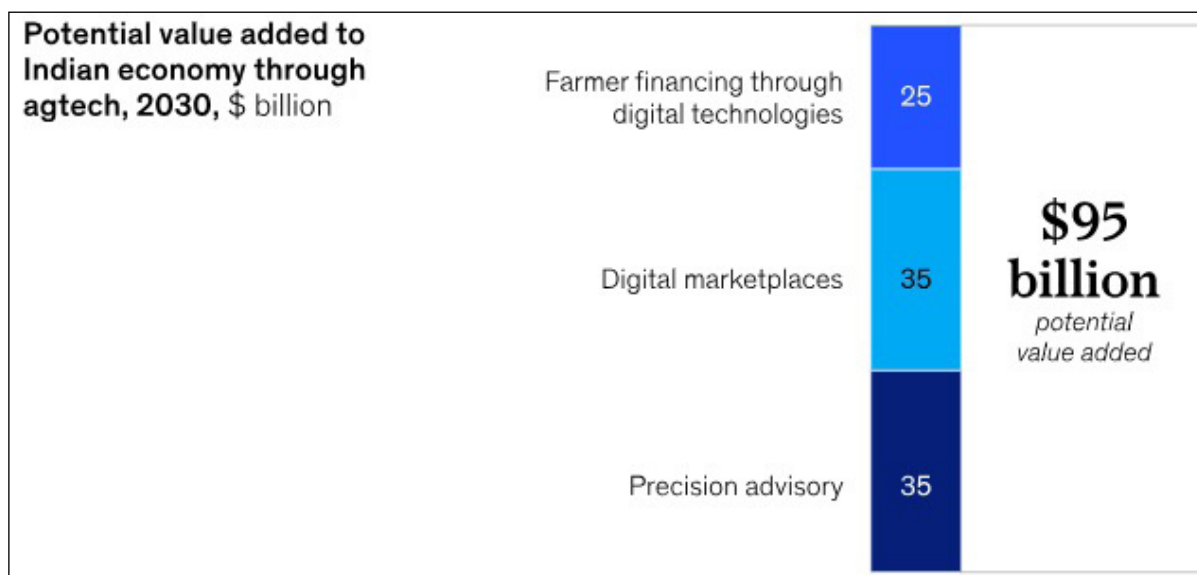
Indian Government has initiated the soil health card proposal for the purpose of soil composition mapping, and this is dedicated in quality of the agricultural product and at the same time quality of agricultural farmers, and altogether this helps in healthy, productive precision farming initiatives and more development in rural aspects (Teye, F. 2012).

Fertilizers systems using ICT

Fertilizers are most important in agricultural systems and farmers are totally depends on different types of fertilizers (Nandyala, C.S. & Kim, H.K. 2016; Ojha, *et al.* 2015). In India there are opportunities to offer digital fertilizer management systems which are helpful for the farmers in different perspective. Adoption of the fertilizers, distribution and record management of the fertilizers used can be effectively possible with such scheme.

National Agriculture Market (e-NAM)

National Agricultural Market or e-NAM is an important initiative in agricultural sector supported by the ICT and Computing. This is an online portal which is connected with the *mandis* and this will be helpful in ensuring best prices for the farmers by the effective and transparent auction process.



Source: McKensy Global Institute Report.

Fig. 2: Predicted digitalization of agriculture within

E Governance in Agricultural Systems

In India different projects related to the Agricultural Systems are ongoing or started such as Kisan Call Center (KCC), Information Village Project of MSSRF (MS Swaminathan Research Foundation), ITCs E-chaupal, Gyandoot Project, IT-Kiosks, Bhoomi Project, Warana weired Village, I-kisan project of Nagarjun group of companies, Village Knowledge Center etc.

Digital public infrastructure-Agricultural context

Government of India very recently has started new fund and system for developing the agro-eco systems, and this is helpful in developing new organizations and start-ups including starting of new digital adoption. There are various services and solutions exists in agricultural sector from digital platform (TongKe, F. 2013). And new age open-source public infrastructure system has been developed and all such system can be considered as impactful and valuable in healthy information infrastructure development (Tsekouropoulos, G. *et al.* 2013).

In India, there are opportunities in digital and smart agricultural systems and therefore a good amount of investment has been made in recent past as per

the report of McKinsey, Jan, 2023 also refer Fig. 3.. Agricultural industry in India is growing rapidly and it is an interesting fact that Indian GDP is more than half itself lies on agriculture. Further India is the largest crop and food producer in the world and it worthy to note that more than twenty percent of India's income considered in central economical part. As per study it has predicts that Indian GDP is expected to increase about 600 billion USD within 2030 and for this about 50% need to increase from the existing contribution of 2020.

Agro Tech Industry and Development of Agricultural Information Systems

India is transforming into a knowledge and digital economy, and therefore different sector specific contribution is impactful and required for the development at large. As far as agricultural sector, it has wonderful contribution in developing economical system supported by agricultural information technology or agro-tech systems (Othman, M.F. & Shazali, K. 2012; Nayyar, A. & Puri, V. 2016). Indian farmers are suffering with various issues, and challenges it include the economical and technological issues. It has reported that maximum number of farms are today suffering with the problem of damages of crop from the pests and weather and a good percentage of farmers are

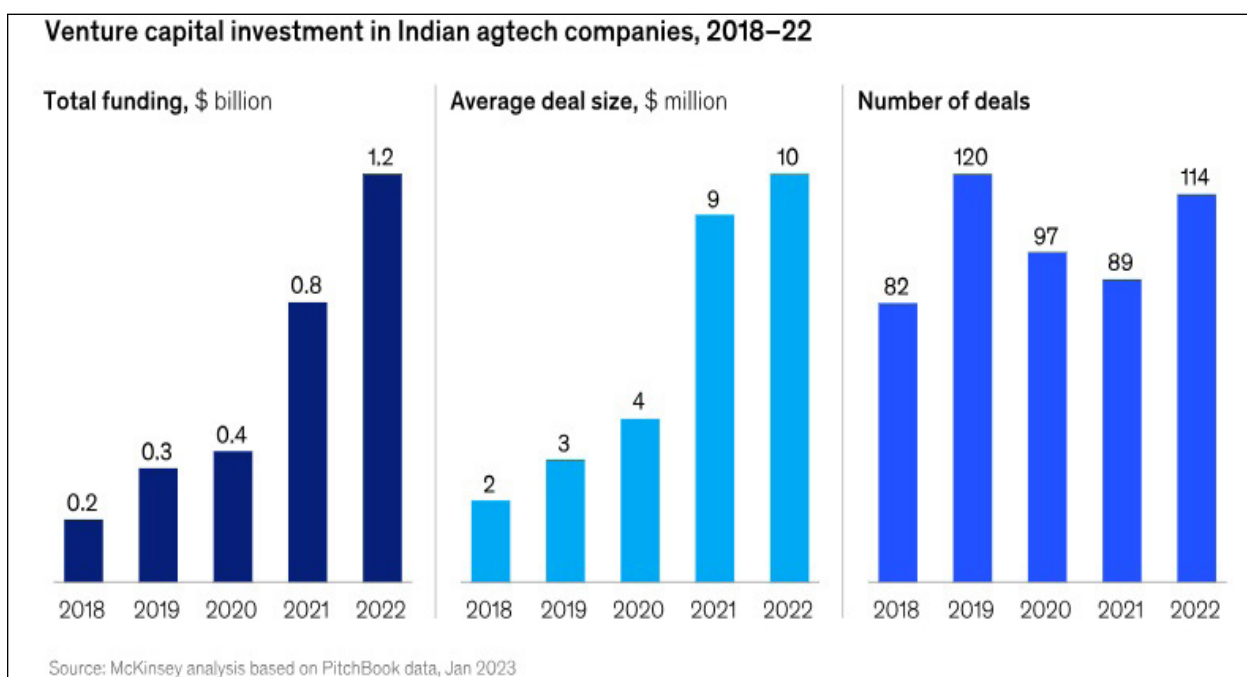


Fig. 3: Investment in agricultural systems and technologies in India during (2018-22)

suffering with the issues of financing the agriculture. And here in each cases wider applications of ICT and Computing applications widely possible and impactful. Applications of proper agricultural tools, technologies and systems deemed to be important in enhancing the profit and boosting the contribution of the GDP; directly and indirectly (Ministry of Agriculture & Farmers Welfare, PIB (2023). Such technological applications no doubt would be valuable in enhancing agricultural production and development. In generally, farmers considered as important stakeholder and they do their business in 'mandis' i.e. the local market for selling the products. The advent of latest computing and systems considered as impactful and important in developing agricultural systems and therefore it also supports in healthy digital eco-systems. Digital technologies and systems now become more farmer and cultivator centric and this results the development of digital agricultural systems and proper supply chain management and enhance the productivity of the seeds supported by the agrochemicals and proper fertilizers (Zamora-Izquierdo, *et al.* 2018). It has reported with 2013-20 the technological organizations connected with agriculture in India grew rapidly from fifty to more than one thousand, and it has results better awareness of the farmers, developed internet systems; both in rural and semi-urban areas. All these are impactful in enhancing efficiency in agricultural systems and sector. The digital technologies are in agriculture changing and enhancing rapid development of agriculture and allied sector. Different stakeholders such as buyers, advisers are considered important in developing agriculture and allied areas. In some of the areas and sectors of agriculture there are direct and indirect uses of technology in agriculture viz. –

- ♦ Various providers of farming supplies like agro-chemicals, fertilizers, etc are highly using technologies for various sales channels creation by the middleman, retailers, etc. digital platform management become possible with Agro-Informatics supported systems.
- ♦ Different kind of firms, banking and nonbanking, financial systems are engaged in offering loans, agro-loans, loans for purchasing technologies related to the agriculture, various farm related apps been developed by many companies and

organizations. And many of such products are offered with the low loan risks.

- ♦ There are companies engaged in selling the technologies and tools to the farmers and other allied personnel.
- ♦ There are firms those who are engaged in procurement, processing of agricultural products and in all such activities related to the technologies. Mahindra, ICT has the operational system and services for the agro product management and marketing as well. Altogether the applications of the ICT in agriculture responsible in advancing and modernizing agro systems including allied systems. And the development phase to the agro systems to be impacted about 95 billion USD in country's economy.

CONCLUDING REMARKS

The basic and advanced Information Technology and Computing changes the entire arena and scenario of traditional agricultural sector including pre and post cultivation and agricultural management. Not only in developed countries, but also in developing countries Agro ICT including latest and emerging applications are booming and leading. In some of the activities such as crop protection, soil management, pre-agro management applications of Computing and Information Technology rapidly developing the scenario of agricultural systems. Among the ICT benefits in agriculture weather related updates, alters, flood related concerns, droughts, pest management and other allied activities are effectively possible and required using ICT and Computing based Agro systems. Disease outbreaks, preventing coming disease from the sensor and AI based system is effectively possible with agro ICT. In marketing management including finding and suggesting a sound, dedicated and reliable market channel identification Agricultural Information System is important and need of the hour. Today mobile phone services are engaged and uses in diverse areas and fields and there are opportunities with such mobile phones. Using mobile phones and additional allied technologies decision making in agriculture and horticulture become possible. Use of latest technologies are impactful to worldwide agriculturists, farmers, agro business professionals. They are able in better connections together and

implementing better and healthy policy and future goals. Use of ICT is important and impactful in better understanding of the situation, agro and rural development. Remote farming using remote observation is effectively possible with healthy and sophisticated agricultural practices. Today ministries, organizations, institutions, private bodies are effectively collaborating and engaging in their benefits using agro-technological systems. Though India has several economical and financial issues but it can be resolved using proper ICT management and computing systems effectively.

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