

Internet of Things (IoT) and Smart Agriculture: With Reference to Applications and Emerging Concern

P. K. Paul¹, R. R. Sinha², P. S. Aithal³, Ricardo Saavedra⁴, Bashiru Aremu⁵ and S. Mewada⁶

¹Executive Director, MCIS, Department of CIS, Information Scientist (Offg.), Raiganj University, India

²Pro Vice Chancellor (Asian Region), Commonwealth Vocational University, Kingdom of Tonga, Oceania

³Vice Chancellor, Srinivas University, Karnataka, India

⁴Director & Chair, International Inter-University Programs, Azteca University, México, North America

⁵Vice Chancellor, Crown University, Intl. Chartered Inc. (CUICI) Argentina Campus, South America

⁶President, International Scientific Research Organization for Science, Engineering & Technology, India

Email: pkpaul.infotech@gmail.com

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Abstract - Agricultural Informatics is one of the important emerging domains gaining popularity in recent years. This is simply the application of Information Technology and Computing in Agriculture and allied activities. This is also the combination of 'Agricultural Science' and 'Informatics or Information Science'. This emerging as an interdisciplinary subject and provides solutions for the smarter agriculture and advancement of the agricultural sectors. It is connected with various kinds of information and technological tools. In the recent past, various IT components have emerged and all these are responsible for the agricultural activities leading to cultivation; its enhancement, productivity, quality, cleanliness, efficiency, post agricultural activities. The Agricultural Informatics is responsible for the design, development, management and implementation of the advanced and intelligent agricultural systems, that may call as 'Smart Agriculture' or it may be called as 'Digital Agriculture'. For the creation of such agricultural systems, various emerging Information Technological tools and technologies are emerging and among these important are Cloud Computing, Big Data, Internet of Things (IoT), Robotics & Artificial Intelligence, Human Computer Interaction, etc. Internet of Things (IoT) is applicable in designing and development of healthy and intelligent information systems that are connected with the internet and similar systems. IoT is responsible for various kinds of Agricultural development activities. This paper is conceptual in nature and deals with a brief overview on Agricultural Informatics including evolution, features and role and importance in the concentration of its applications in the creation of 'Smart Agriculture' and also emphasized how IoT and similar systems are helpful in promotion of Agricultural activities, intelligent and smarter way. Paper also highlighted about the issues, challenges and concerns on Agricultural Informatics with special reference to its IoT applications in Agriculture towards the promotion of Smart Agriculture.

Keywords: Agricultural Informatics, Interdisciplinary Sciences, IC4DT, Smart Agriculture, Digital Agriculture

I. INTRODUCTION

Smart Agriculture is the result of Agricultural Informatics applications in different activities of agriculture and related activities. It is to be noted that Agricultural Informatics required in healthy practice of agriculture which includes the cultivation of crops, seed, plants, vegetables, as well as animals, etc by the assistance of various technologies,

methods, tools, etc. farming is considered as smaller than agriculture and mainly considered with the need of the family on other hand, agriculture is consider as more commercial intensive and conducted in large scale and places [1], [7], [24]. Here miscellaneous methods are used also; and thus, also called as Industrial Agriculture. Agricultural Informatics is applicable in agriculture including other areas viz. horticulture, veterinary sciences, geography, etc. Agricultural Informatics is also popular with other nomenclature such as

1. Agricultural Information Technology,
2. Agricultural Information Systems
3. Smart Agriculture
4. Digital Agriculture
5. Agricultural Data Sciences, etc

For building Smart Agriculture various Technologies, Information and management techniques play a leading role. Internet of Things, in short, called IoT, is responsible for intelligent system development with the help of internet connected and sensor based tools. IoT is emerging and gaining popularity around the world and it is widely applicable in other diverse areas. As far as, Agriculture is concerned, it has an emerging and wider role. IoT, however, takes help in other systems and technologies for its real fulfillment [12], [17], [32].

II. OBJECTIVES

This paper entitled, 'Smart Agriculture powered by Agro Informatics with reference to Internet of Things (IoT) Integration—An Analysis' is theoretical and policy based work and deals with following (but not limited to)—

1. To get basic knowledge which helps in the constituency of Agricultural Informatics and a brief on Computer Science, Computer Applications, Information Technology as well as other allied nomenclature.
2. To find out about the basics as well as types of the Agricultural Sciences and field, briefly.

3. To learn about the features, functions and role of Smart Agriculture with its stakeholders.
4. To get the emerging applications of Information Technology in the agricultural as well as other activities.
5. To know the basics of the Internet of Things; including its origin, foundations and features in brief.
6. To learn about the applications of the Internet of Things (IoT) in diverse areas in brief with reference to the framework of IoT.
7. To get the knowledge about the Internet of Things applications in Agriculture and allied areas towards a Smart Agricultural system.
8. To learn about the academic programs, training and academic availability for the promotion of Smart Agriculture.
9. To know a brief on issues, challenges on the implementation of the Smart Agriculture vis-a-vis Agricultural Informatics in practices as well as in academics.

III. SMART AGRICULTURE VIS-À-VIS AGRICULTURAL INFORMATICS: THE FOUNDATION & FEATURES

Agricultural Informatics is an important merging domain of Agricultural Sciences and on the other hand, Informatics/Information Science. The combination of both is called as Agricultural Informatics and also Agricultural Information Technology [10], [20], [28]. Literary though, the meanings are different but it is practically considered as the same or equivalent. As we are aware that Agricultural Science is about the agriculture and uses of scientific tools, techniques, methods, policies and regulations in basic cultivation; large scale agriculture of different items. As far as items are concerned, most important and valuable are the crops, seeds, vegetables, plants as well as animals, etc. It is worthy to note that, in Agricultural Sciences and systems there are many new concepts are emerging such as-

1. Agricultural Chemistry
2. Green revolution & Agriculture
3. Genetic engineering based Agriculture
4. Organic Agriculture /Farming
5. Corporate Agriculture /Farming/Vertical Farming

In all these and particularly in Industrial Agriculture, Information Technology is mostly useful. Before reaching in detail, let us learn about the basics of these subjects. Information Technology is a field and practicing area responsible for the different kinds of information activities with the help of various technologies viz. Database Technology, Multimedia Technology, Networking Technology, Software Technology, Web Technology, etc. This field is less mathematical and concentrated on information systems designing and development. As far as Computer Science is concerned, it is about the designing and development of systems; especially the hardware centric. Further it is mathematical in nature. As far as

Computer Application is concerned it is mainly application oriented and mainly responsible for the designing, development of the software systems. The field, Informatics and Information Science is more or less similar. Information Science can be considered as the interdisciplinary field with applied nature and uses various tools of IT and additionally management techniques, tools and procedures. Further, it is mainly connected with society and common people due to its nature [7], [22], [30]. The branch Informatics in some context considered as a practicing area whereas Information Science as a field of study. Hence Agricultural Informatics is a broad and applied domain and further on this emerging domain can be gathered from the following

1. Agricultural Informatics is a kind of interdisciplinary combination of horticulture, veterinary sciences, ecology, Computer Science, IT, Informatics, Information Science, etc.
2. Agricultural Informatics lies on the nature of technological, social, ecological studies and further it is dedicated to the Agricultural business development and promotion.
3. Information or knowledge or data, etc consider as important and it is applicable in a diverse area of Agricultural Informatics including pre and post production of Agricultural activities.
4. Agricultural Informatics is technology depended as it deals with many computational systems/ technologies and information technology
5. Smart agricultural or Digital Agriculture become easy with Agro Informatics with the help of its technologies. Hence it is changing nature including nomenclatures.
6. Professionals aspects including training, manpower development, leadership, management principles are the important fact of the Agricultural Informatics
7. Ecology and sustainability are directly and indirectly associated with the Agricultural Informatics and allied subjects; hence Agro Informatics is dedicated to sustainable development.
8. As far as the Internet of Things (IoT) is concerned it is widely emerging and recognized in the recent past due to its wonderful benefits. Agricultural Informatics can get a wider benefit of this and ultimately may help to develop Smart Agriculture positively [11], [23], [27].

IV. IOT: THE FOUNDATION, FEATURES AND FRAMEWORK

Internet of Things is an emerging technology and popularly known as IoT. It deals with different types of objects and sensors with this. In industrial machines to wearable devices in diverse areas, IoT is applicable. The term first coined by Entrepreneur Kevin Ashton (he was also considered as founder, Auto-ID Center, MIT, Massachusetts) in the year 1990s. Gradually huge development we have seen on the Internet of Things (IoT); and in recent past just booming.

In Internet of Things (IoT) normally various built-in sensors communicate and also collect data; and thereafter perform

other roles. Hence in the Internet of Things (IoT) internet and network play a leading role. In many activities, this becomes an important name viz. automatic adjustment of heating and lighting, etc. IoT is one of the promising future technology for efficient and digital society development. Here in devices and objects, an IP address uses for collection, and further activities with data and it is applicable in various areas such as Businesses and Financial Affairs; Agricultural & Horticulture, Education and Training; Government and Leadership; Hospital and Health Systems; Transportation of various kinds; Manufacturing and Infrastructure, etc. In the Internet of Things (IoT), the wireless Internet and network, embedded sensors, etc are considered as an important technology and therefore applicable in professional as well as in common services for human being [13], [25], [31]. IoT architecture is thus also

towards more complicated each and every time (refer Fig:1).

1. Internet of Things (IoT) can be considered as advanced information solutions based on internet and allied technologies.
2. Internet of Things (IoT) depends on various kind of allied technologies such as Cloud Computing, Data Analytics, Human Centered Computing, etc.
3. It is a kind of sensor dependent technology. Moreover, here Smart electric grids can play a leading role with renewable resources on smaller usage increments.
4. Internet of Things (IoT) is based on machine monitoring sensors and ultimately dedicated to intelligent machine and systems development [2], [6], [18].

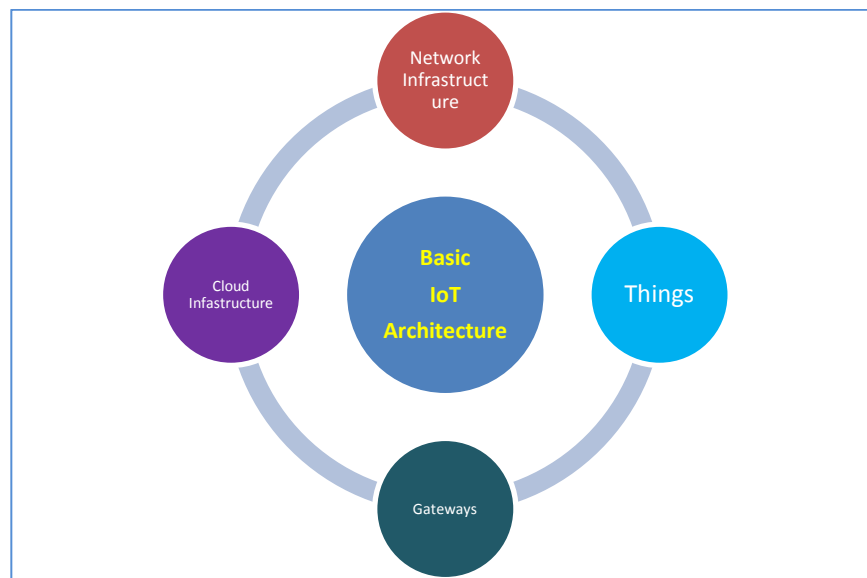


Fig.1 The basic Iot architecture

V. IOT: THE EMERGING APPLICATIONS

Due to wider benefits of the Internet of Things (IoT) viz. increases efficiency, safety, productivity, super security it is applicable in a wide range of areas such as healthcare, infrastructure, transportation, business, agriculture, retail sectors, etc. Internet of Things (IoT) is applicable in diverse areas and it could be on following areas viz.-

1. The users
2. Commercial Uses
3. Organizational and
4. Infrastructure spaces, etc.

Internet of Things (IoT) is a great name for the applications of in other areas but in recent past in most emerging areas are home automation & smart home development. Here IoT devices are applicable in automated air conditioning, lighting, heating, water systems security systems in various areas of the home. Here smart devices such as iPhone or

iOS native are considered valuable, similar to Smart Home another allied one is Smart Buildings dedicated additionally in reducing energy consumption, automated operation, etc.

Internet of Things (IoT) is also applicable in a few other areas such as in old aged caring, mainly by offering automated services and most suitable for the person with disabilities and elderly individuals. In this context additionally, assistive technology, voice control systems, etc are useful including a role in medical emergencies [5], [14], [26]. Smarter Healthcare is also powered by the IoT in the activities of collection, analysis of data and also for the healthy medical informatics practice with proper medical resources, remote healthcare, m-health, tele-medicine, e-nursing become possible with this. In the transportation system such as in the areas of managing the vehicle, Smart traffic control systems, advanced electronic toll collection, etc, the IoT is very much important. The infrastructure management and HRM, emergency and road safety IoT are amazing.

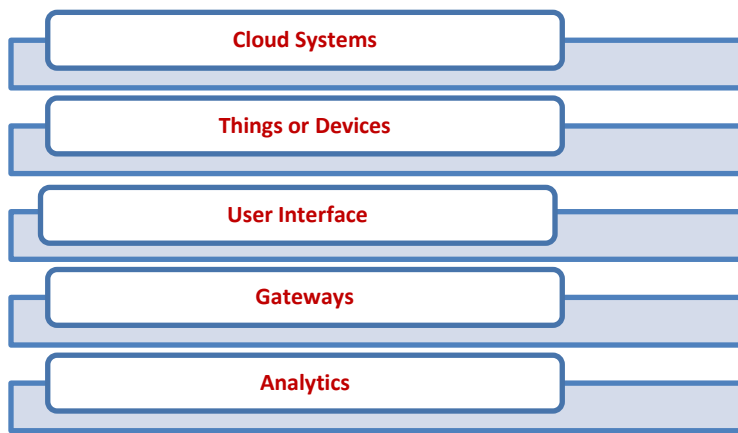


Fig. 2 Major components of iot

In Manufacturing, IoT is working in the Network control of manufacturing equipment, rapid manufacturing, smarter supply chain systems, etc. Further due to its role it is also called as Industrial IoT (IIoT). And in many other areas, IoT become an important tool. Further, for all such activities all the major components of IoT play an important role (Fig: 2).

VI. SMART AGRICULTURE & IOT: THE SCENARIO

The application of Information Technology plays a leading role in modernizing and advanced Smart Agricultural practice. Internet of Things (IoT), as an emerging tool and technology, is also developing smarter and digital agriculture with better agricultural efficiency, reduction, enhancing productivity, minimization of the resources, enhancing more automation, etc [8], [9], [27]. The applications of Internet of Things (IoT) in creating Digital and Smarter Agriculture by the following means and ways.

A. Efficiency and Agriculture

With the help of the Internet of Things (IoT), monitoring of agricultural products becomes easy and possible to know the conditions in real-time. With IoT the prediction possible and easiest and further it can be helpful in the promotion of Need based or demand-based irrigation, healthier Agro fertilizing, automated harvesting and cleaning of the cultivating zones, more helps in weather prediction and climate analysis, etc. As a result, it will help in further efficiency in agricultural systems.

It is important that about 70% of the population are the resident of urban areas and here IoT-based greenhouses can be helpful and will help in Expansion of Agriculture in diverse areas. In the recent past, Smart closed-cycle agricultural can be a good place with the applications of different attributes of the Internet of Things (IoT).

B. Smart Agriculture & Resource Reducing

With the help of emerging sensors, optimization systems various activities become easy such as the management of corps, water, energy, land, etc. Hence here the collected data from different sorts is helping also in managing pesticides, fertilizers, etc. Hence, precision farming becomes possible effectively. Internet of Things (IoT) applications hence reduces the resources. Further Internet of Things (IoT) helps in cleaning as well as green strategy. Ultimately it helps in greener farming and sustainable cultivation. Hence Internet of Things (IoT) is helpful in the promotion of organic agriculture.

C. Faster Agricultural Systems by IoT

As the Internet of Things (IoT) helps in real-time monitoring in addition to the support of AI and ES based prediction systems; hence it helps in cultivators for quick agriculture. The situations including the weather, humidity, and soil conditions are possible to analyze with the help of the Internet of Things (IoT) based systems. In addition to these, the health of crops, weather changes, etc can be easily possible to get by the Internet of Things (IoT) and other components of Agro Informatics. Ultimately this way, the Internet of Things (IoT) helps in fasters and smarter agriculture [15], [22], [28].

D. Quality and Quantity in Production vs. IoT

Aerial drone monitoring is integrated with the sensors. This is thus helpful in farm mapping, including a better understanding of agro, as a result of this quality of the crops, plants, vegetables, etc can be analyzed. Internet of Things (IoT) in Agriculture is called Agro IoT or A IoT; which leads to better quality of cultivating products. Hence with this, the nutritional value of the corps, vegetables can be analyzed. With the Internet of Things (IoT) in Agriculture even a few other things possible to get viz. temperature, rainfall, humidity, speed of the wind, etc. Thus, automated farming becomes possible and helps in quality in agriculture by different sorts.

E. Climate & IoT: Smarter Agriculture

Weather including the climate is very important in agriculture and cultivation. The attached sensors and IoT based systems thus help in weather analysis and prediction. Hence with this, crop productions become easier. IoT helps in real-time weather condition detection including in humidity, rainfall, temperature, etc by its sensor enable IoT and AI based tools. Therefore, monitoring the condition of crops, fields, as well as the weather becomes possible with intelligent IoT. This helps in decision making in farming; and additionally, with this, there is no need for the physical presence of the cultivators during bad climatic conditions. Thus, promotes in remote cultivation [3], [4], [16].

F. Precision Cultivation & IoT

Precision Agriculture is an emerging concept and in this Internet of Things (IoT) is helpful by different means. This helps in farming practice efficiently with preciseness. Therefore, it will help in the following—

1. Livestock monitoring of agricultural products.
2. Easiest and effective field study.
3. Inventory as well as budgetary control and monitoring,
4. In promotion of the transportation management.

As here sensors play a leading role therefore it helps in the cultivation unit with quicker decisions and ultimately will help in Smarter Precision in Cultivation.

G. Green House Perfect

IoT has made smarter and intelligent weather stations which intelligently control the climate conditions as per the set of instructions. IoT in Greenhouses reduces human intervention and the ready systems become cost-effective, more accurate. Solar-power based IoT sensors helps in modern and inexpensive greenhouses. Due to real time data collection and monitoring greenhouse can be in a very precise manner in real-time situations. Even the water consumption can be monitored by the intelligent systems viz. emails or SMS alerts and as a result, these sensors come with the information on the sunlight levels, pressure, humidity, temperature. And all these are possible by IoT based Agriculture [15], [19], [21].

The popularity of IoT is increasing rapidly day by day and it is predicted more IoT devices in the coming days (Source: the IoT magazine), refer: Fig. 3.

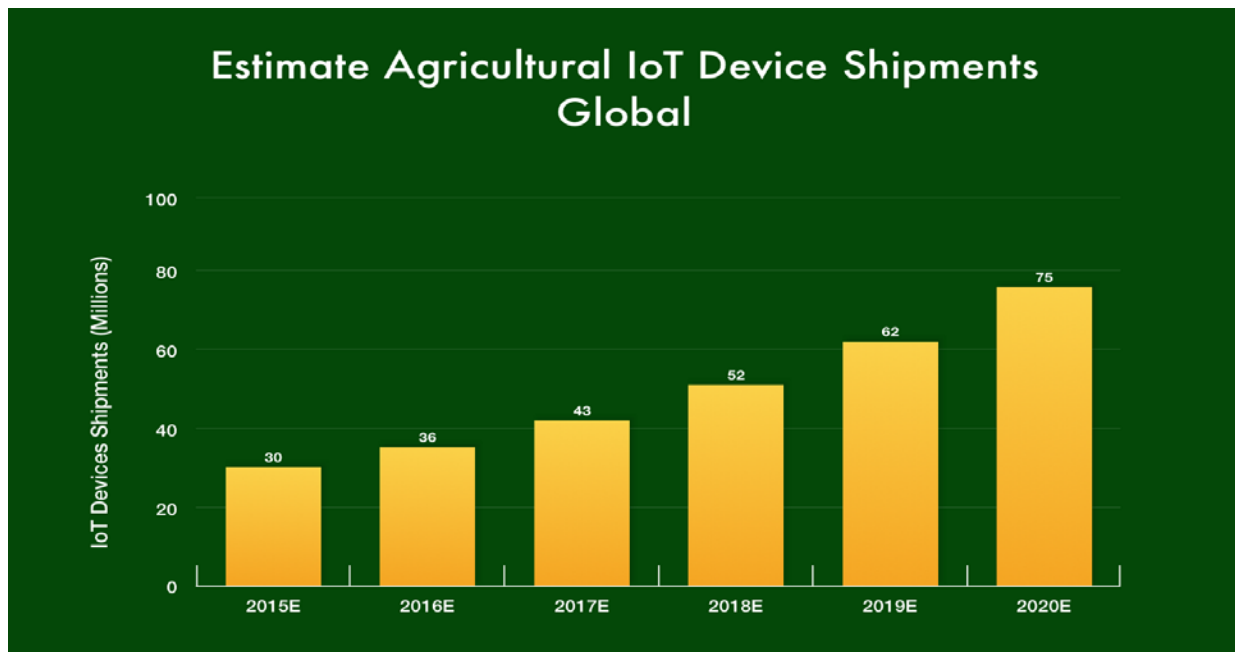


Fig. 3 Growing IoT in Agriculture

H. Data Analytics and Management

Internet of Things (IoT) and allied technologies are important in the building of Digital Agriculture. Apart from that traditional component of Information Technology, here various other emerging technologies play a leading role in the fulfillment of the aim and objectives. Here IoT based sensors play an important role in the collection of data on

large scale [5], [24]. The combination of the Big Data Analytics and Management along with IoT helps in different activities in smart agricultural promotion viz. the analysis of the weather conditions, gathering knowledge on livestock and products, crops conditions, healthy and intelligent decision making, real time data gathering on corps, seed, plants and vegetable growth, etc. Predictive analytics helps in harvesting including upcoming weather,

etc, which ultimately helps in enhancement of the agricultural product volume and quality. Hence this way, IoT and other emerging technology helping in the creation of sustainable and smarter agriculture (Refer fig: 4).

I. Smart and remote based agriculture

Agricultural drones are required in the ground as well in the aerial view. Hence this (Thermal or multispectral sensors based drones) helps in gathering of information which will help in knowing crop health. Further with this, crop monitoring & spraying become possible. With the Internet

of Things (IoT) based systems even fieldwork management and analysis possible with the uses of drone technology. The technology provides us real time data, videos and multimedia contents. And, all these results in better agriculture industry output. Moreover, the massive reduction in chemical reaching the groundwater are also possible with the Internet of Things (IoT) based drones.

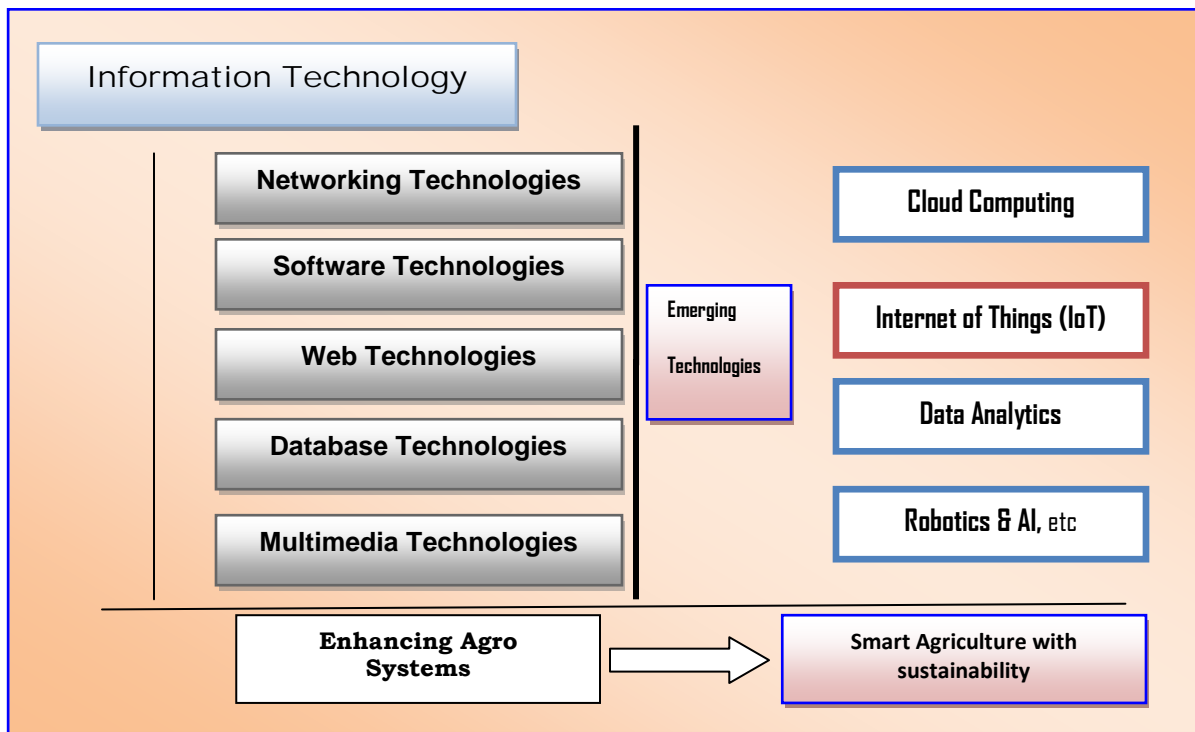


Fig.4 Sustainable agriculture powered by Iot and other emerging technologies

J. Smarter Livestock Management

Internet of Things (IoT) is associated with the wireless IoT and this ultimately helps in the agro business and industries. This ultimately helps in manpower development and reduction of labor costs. Moreover, various vegetables, different animals (such as cows, sheep, pig, etc) are manageable with the Internet of Things (IoT) based systems that help in reaching smarter livestock management.

K. Smarter Environmental Monitoring

Internet of Things (IoT) can bring healthy and efficient energy management. And this may be applicable in diverse areas for energy management viz. computers, devices, networking systems, switches, televisions, drones, IoT based systems, etc. Hence Internet of Things (IoT) also helps in environmental protection by IoT viz. use of monitoring air or water quality. Moreover, with the Internet

of Things (IoT), the movements of wildlife and their habitats can be analyzed, different disaster management related issues can be used with Internet of Things(IoT) based systems. IoT is increasing with a 31% increase rate and expected 30 billion devices (by the end of 2020)with a value of \$7.1 trillion by the end [7], [27].

L. Smart Agriculture: Issues & Challenges

Internet of Things (IoT) is an amazing tool in Agriculture Management. This will promote Cultivation Systems by different means. However, there are certain issues, challenges and issues with the implementation of the Smart Agriculture viz.

1. Internet of Things (IoT) implementation in agriculture comes with various devices such as sensors, cameras, robots, drones, etc and all these are costly including implantation and operation and maintenances.

2. Internet of Things (IoT) applications in Agriculture is led the concept of Agro Internet of Things (AIoT). Though it needs skilled HR for the activities of implementation, managing and obviously its uses, etc.
3. Recurring maintenance budget on hardware and devices is an important issue in implementation and continuing IoT in Agriculture especially Smart Agriculture, etc.
4. The unscientific supply chain management basically reduces the efficiency in some context; hence it is considered as an important issue in the implementation of the Internet of Things(IoT) in agriculture, etc
5. Integration with existing implemented devices with new is challenging in some context for better and smarter agricultural practices.
6. Continuous technological support viz. internet, electricity is very important in implementing and operation of the Agro Internet of Things (AIoT) Systems to reach healthy and smarter agriculture.
7. Availability of Manpower in the field is an issue; still, there is a gap in real production on skilled, educated manpower in this field. Hence better to start educational programs on different levels on this subject and allied subjects mentioned above.

VII. CONCLUSION

Internet of Things (IoT) is gaining rapidly as emerging tools and technologies. It is an amazing tool that makes individuals' lives easier with efficient and smarter systems in different fields. However, as far as Smart Agriculture is concerned Agricultural Informatics plays a leading role in its realization and implementation. Agriculture is one of the important sectors worldwide irrespective of the status of the nation viz. developed, developing and undeveloped. Historically, agriculture is one of the oldest professions and till the highest number of occupation providers in the world. There are a variety of jobs and occupations available with agriculture directly and indirectly. In the pre agricultural and post agricultural systems technologies and computing are very important. Thus, in recent years gradual involvement of the technologies in agriculture is noticeable. Though there are certain issues and challenges but with proper initiatives more healthy and sustainable agriculture is possible. Manpower development has become an important issue in modernizing agriculture systems, hence for the creation of Digital and Smarter Agricultural Systems, there should be a proper arrangement in agriculture informatics and allied technologies in different levels including research. In a developing country also, there are massive growth in such technologies and this trend is valuable due to smarter agro business as well.

REFERENCES

- [1] Abbasi, A. Z., Islam, N., & Shaikh, Z. A., "A review of wireless sensors and networks' applications in agriculture," *Computer Standards & Interfaces*, Vol. 36, No. 2, pp. 263-270, 2014.
- [2] Adão, T. *et.al.*, "Hyperspectral imaging: A review on UAV-based sensors, data processing and applications for agriculture and forestry," *Remote Sensing*, Vol. 9, No. 11, pp. 1110-1120, 2017.
- [3] Adetunji, K. E., & Joseph, M. K., "Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture". In *2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)* (pp. 4849-4854), 2018
- [4] Ahmad, T., Ahmad, S., & Jamshed, M., "A knowledge based Indian agriculture: With cloud ERP arrangement". In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)*, pp. 333-340, October, 2015
- [5] Aubert, B. A., Schroeder, A., & Grimaudo, J. "IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology," *Decision support systems*, Vol.54, No. 1 , pp. 510-520, 2012
- [6] Babu, S. M., Lakshmi, A. J., & Rao, B. T. "A study on cloud based Internet of Things: CloudIoT". In *2015 global conference on communication technologies (GCCT)* (pp. 60-65). IEEE, April, 2015
- [7] Balamurugan, S., Divyabharathi, N., Jayashruthi, K., Bowiya, M., Shermey, R. P., & Shanker, R., "Internet of agriculture: Applying IoT to improve food and farming technology", *International Research Journal of Engineering and Technology (IJRET)*, Vol. 3, No. 10, pp.713-719, 2016
- [8] Bauckhage, C., & Kersting, K., "Data mining and pattern recognition in agriculture," *KI-Künstliche Intelligenz*, Vol.27, No. 4 , pp. 313-324, 2013
- [9] Channe, H., Kothari, S., & Kadam, D., "Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis," *Int. J. Computer Technology & Applications*, Vol. 6, No. 3, pp. 374-382, 2015
- [10] Gill, S. S., Chana, I., & Buyya, R., "IoT based agriculture as a cloud and big data service: the beginning of digital India," *Journal of Organizational and End User Computing (JOEUC)*, Vol. 29, No. 4, pp.1-23, 2017
- [11] Gómez-Chabla, R., Real-Avilés, K., Morán, C., Grijalva, P., & Recalde, T. "IoT Applications in Agriculture: A Systematic Literature Review". In *2nd International Conference on ICTs in Agronomy and Environment*, pp. 68-76, 2009
- [12] Goraya, M. S., & Kaur, "H. Cloud computing in agriculture". *HCTL Open International Journal of Technology Innovations and Research (IJTIR)*, Vol. 16, pp. 2321-1814, 2015
- [13] Guardo, E., Di Stefano, A., La Corte, A., Sapienza, M., & Scatà, M., "A fog computing-based iot framework for precision agriculture", *Journal of Internet Technology*, Vol. 19, No. 5, pp. 1401-1411, 2018
- [14] Kamble, S. S., Gunasekaran, A., & Gawankar, S. A., "Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications," *International Journal of Production Economics*, Vol. 219, pp. 179-194, 2020
- [15] Kajol, R., & Akshay, K. K., Automated Agricultural Field Analysis and Monitoring System Using IOT. *International Journal of Information Engineering and Electronic Business*, 11(2), 2018
- [16] Khattab, A., Abdelgawad, A., & Yelmarthi, K. Design and implementation of a cloud-based IoT scheme for precision agriculture. In *2016 28th International Conference on Microelectronics*, pp. 201-204, IEEE, December, 2016
- [17] Liu, S., Guo, L., Webb, H., Ya, X., & Chang, X. Internet of Things monitoring system of modern eco-agriculture based on cloud computing. *IEEE Access*, Vol. 7, pp. 37050-37058, 2019
- [18] Manos, B., Polman, N., & Viaggi, D. "Agricultural and environmental informatics, governance and management: Emerging research applications," Z. Andreopoulou (Ed.). IGI Global (701 E. Chocolate Avenue, Hershey, Pennsylvania, 17033, USA, 2011
- [19] Muangprathub, J., Boonnarn, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P., "IoT and agriculture data analysis for smart farm". *Computers and electronics in agriculture*, Vol. 156, pp. 467-474, 2019

- [20] Na, A., & Isaac, W, Developing a human-centric agricultural model in the IoT environment. In *2016 International Conference on Internet of Things and Applications (IOTA)* pp. 292-297, IEEE, January, 2016
- [21] Nandyala, C. S., & Kim, H. K., "Green IoT agriculture and healthcare application (GAHA)". *International Journal of Smart Home*, Vol. 10, No. 4, pp. 289-300, 2016
- [22] Othman, M. F., & Shazali, K, "Wireless sensor network applications: A study in environment monitoring system," *Procedia Engineering*, Vol. 41, 1204-1210, 2012
- [23] Ozdogan, B., Gacar, A., & Aktas, H., Digital agriculture practices in the context of agriculture 4.0. *Journal of Economics Finance and Accounting*, Vol. 4, No. 2, pp. 186-193, 2017
- [24] Paul, Prantosh Kumar Minakshi Ghosh, Dipak Chatterjee, "Information Systems & Networks (ISN): Emphasizing Agricultural Information Networks with a case Study of AGRIS". *Scholars Journal of Agriculture and Veterinary Sciences*, Vol. 1, No. 1, pp. 38-41, 2014
- [25] Paul, Prantosh Kumar, "Information and Knowledge Requirement for Farming and Agriculture Domain". *International Journal of Soft Computing Bio Informatics*, Vol. 4, No. 2, pp. 80-84, 2013
- [26] Paul, Prantosh Kumar et al, "Agricultural Problems in India requiring solution through Agricultural Information Systems: Problems and Prospects in Developing Countries," *International Journal of Information Science and Computing*, Vol. 2, No.1, pp. 33-40.
- [27] Paul, Prantosh Kumar *et al.* "Cloud Computing and Virtualization in Agricultural Space: A Knowledge Survey". *Palgo Journal of Agriculture*, Vol. 4, No. 2, pp.202-206, 2016
- [28] Paul, Prantosh Kumar *et al.*, "Information and Communication Technology and Information: their role in Tea Cultivation and Marketing in the context of Developing Countries—A Theoretical Approach". *Current Trends in Biotechnology and Chemical Research*, Vol. 5, No. 2, pp. 55-161, 2015
- [29] Rezník, T., Charvát, K., Lukas, V., Charvát Jr, K., Horáková, Š., & Kepka, M., "Open data model for (precision) agriculture applications and agricultural pollution monitoring". In *EnviroInfo and ICT for Sustainability 2015*. Atlantis Press, Sept. 2015
- [30] TongKe, F. "Smart agriculture based on cloud computing and IOT," *Journal of Convergence Information Technology*, Vol. 8, No. 2, pp. 210-216, 2013
- [31] Tsekouropoulos, G., Andreopoulou, Z., Koliouka, C., Koutroumanidis, T., & Batzios, C, "Internet functions in marketing: multicriteria ranking of agricultural SMEs websites in Greece" *Agrárinformatika/journal of agricultural informatics*, Vol. 4, No. 2, pp. 22-36, 2013.
- [32] Zamora-Izquierdo, M. A., Santa, J., Martínez, J. A., Martínez, V., & Skarmeta, A. F." Smart farming IoT platform based on edge and cloud computing". *Biosystems engineering*, Vol. 177, pp. 4-17, 2013