

Agro Informatics with Reference to Features, Functions and Emergence as a Discipline in Agricultural Sciences: An Analysis

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

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

E-mail: pkpaul.infotech@gmail.com

Abstract - There are many interdisciplinary subjects worldwide and this trend is growing rapidly. Among these subjects, one of the important is Agricultural Information Science. Information Science deals with the nature of Interdisciplinary Sciences and falls under the category of Applied Sciences. The field is very much synonymously and treated as equal to Informatics in some countries. The branch therefore also called as Agro Informatics and consists with both practicing nature and as a field of study. The applications of IT and Computing in other subjects and areas led to the development of other subjects such as Bio Informatics, Geo Informatics, Health Informatics, etc. Agricultural Informatics is growing rapidly and emerging as a field internationally in many countries. IT and computing applications in different areas, sectors and subjects including societal areas are considered as Information Science. Thus, Agricultural Informatics is socially connected or touched. Thus, the applications of Computing including the latest technologies in agriculture and allied areas treated as Agricultural Informatics. Though it is the application of more than technologies and includes the techniques, methodologies, procedure, etc into Agriculture. Agricultural Informatics is the analysis, management, and processing of agricultural data with the help of IT Systems. Agriculture is also an interdisciplinary field and responsible for cultivating or producing the food, feed, fiber, corn, various plants, vegetables including the domesticated animals with scientific methods. Agricultural Informatics is therefore an interdisciplinary area combines with both Agricultural

Sciences and allied areas with IT & Computing. This paper is theoretical as well as conceptual in nature and deals with mainly various aspects of Agricultural Informatics viz. foundation, nature and characteristics, role and functions in detail. It also briefly explores about the stakeholders and technologies of Agro Informatics.

Keywords: Computing, IT, Agricultural Informatics, Agro ICT, Academics, Universities, Degrees, Interdisciplinary Sciences

I. INTRODUCTION

The practicing of agriculture with the help of various methods, tools farming is called as agriculture. Normally cultivation and farming are treated to happen in a small area; maybe to reach the need of a family. On other hand, agriculture may be considered as a commercial intensive and involves not only plants, seeds, and corps but also animals with huge places and methods. This is also called as Industrial Agriculture [2], [26]. Computing and IT applications in the agriculture and allied areas have created the area of Agricultural Informatics. In Agro Informatics, information, and technologies (i.e. mainly IT) play a leading role. Information is the prime movers in development and in Agricultural areas as well (refer Fig: 1 to get knowledge on Information)

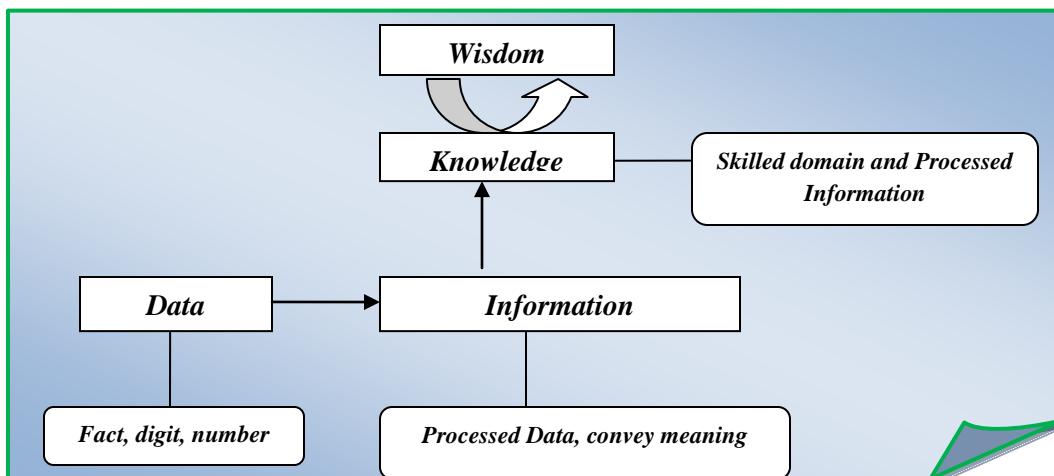


Fig.1 Basic of information and its smaller and larger gradients

Initially, only the Agriculture industry is considered as uses or stakeholders in Agricultural Informatics; though in recent past other subjects such as horticulture, veterinary sciences, geography, ecology, and environment are also treated as important users of Agricultural Informatics. The field is become more valuable and widely practiced in developed countries, whereas in developing nations wise it is started to practice directly and indirectly by various means [5], [7], [27]. The term Agricultural Informatics, however as a field of also offered in other nomenclature viz.—Agricultural Information Technology, Agricultural Information Systems and even more Agricultural Data Sciences.

II. OBJECTIVES

The paper entitled ‘Agro Informatics with reference to features, functions and emergence as a discipline in Agricultural Sciences—An Analysis’ is theoretical in nature and deals with foundations and proposal as well on following aim and objects (but not limited to)

1. To learn about the term Informatics including allied nomenclature with the basics of Agricultural Informatics, in brief.
2. To learn basic knowledge in Information Science as well as Agricultural Sciences, and their integration in Agricultural Informatics.
3. To learn about the basic features, characteristics and changing scenario of Agricultural Informatics.
4. To learn about the emerging applications of Agricultural Informatics and allied fields in the promotion of agricultural activities.
5. To get the knowledge on Agricultural Informatics related educational programs in brief, with few possible programs with emerging titles/ nomenclature of emergence.
6. To learn about the issues, challenges, of Agricultural Informatics practice and academics.

III. AGRICULTURAL INFORMATION SCIENCES: THE FOUNDATION

Agricultural Information Science is a merged domain of Information Science (i.e. Informatics) and Agricultural Science (Agriculture). Before learning in detail about this, let us know some of the basics

Information Sciences is emerging applied science and a field of interdisciplinary studies. It is dedicated to the core information activities such as Collection, Selection, Organization, Processing, Management Dissemination [8], [12], [28]. Though, evaluation is also considered as an important activity with proper feedback. This is also called as Informatics in a few countries and regions.

Information Technology and Information Science are related but there is a basic difference within two and mainly the role and way to sever. Information Technology (IT) is

applied in nature and concentrated on technological systems; however, Information Sciences additionally also deals with manual information systems and technological nature.

Information Science is broader than allied subjects viz. Computer Science, Computer Engineering Computer Applications, IT, Information Systems, etc [1], [3], [10], [30].

The aim/ agenda also differ among these two, mainly in technologies. IT uses core components as database technologies, networking technologies, web technologies, multimedia technologies, etc.

Whereas, Information Sciences uses such in information activities and helps in different sectors by applications and integrations viz. Education and Research, Government, and Management, Business and Industries, Healthcare Systems, Transportation Systems, Entertainment Sector, Social Development, etc [6], [9], [24], [34].

In addition to these sectors, Information Sciences are also applicable in other fields and disciplines viz.

1. Biological Sciences,
2. Pure Science,
3. Mathematical Sciences,
4. Chemical Sciences
5. Social Sciences, etc.

The Agricultural Informatics is the result of integration of Agro and Informatics and can be treated within the category of Biological Information Sciences (further is depicted in Fig: 2)

In addition to core IT components mentioned above, in the latest Informatics few emerging technologies are booming viz.

1. Cloud Computing and Technologies
2. Robotics and AI
3. Green Computing and Systems
4. Human Computer Interactions
5. Usability Engineering
6. Big Data Management
7. Data Analytics, etc [11], [15], [29].

All these emerging technologies are applicable in agricultural activities also; directly and indirectly by different means; and details are provided in the next section (Function of Agro Informatics).

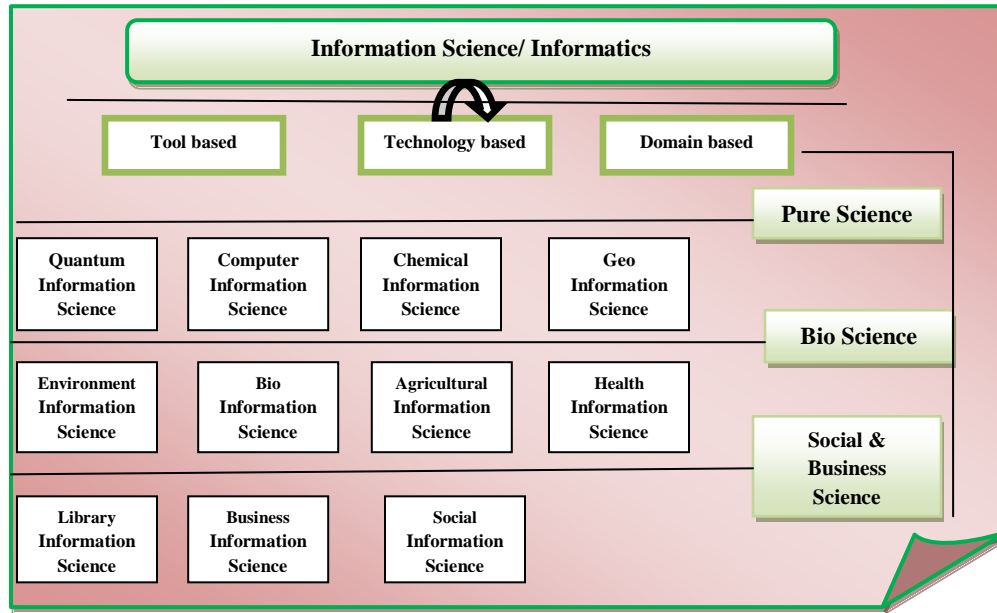


Fig.2 Domain based information science at a glance.

IV. SERVICE SCIENCE, INFORMATION SCIENCE AND AGRICULTURE

Service Science is a concept and even a field of study and emerging rapidly. Due to its nature, it is interdisciplinary in nature dedicated to the affairs related to the services viz. service promotion, delivery as well as hospitality. Service Science is dedicated in enhancement of the service as a system including organizations, people, technology,

businesses [13], [17], [33]. Information Science is holding the nature of Service Science as it is applicable in different subjects and areas; whereas Agricultural Sciences also holds the same feature (Refer fig: 3).

Agricultural Informatics is a combined branch of both the fields holding more service centric nature and improving rapidly [14], [18], and [29].

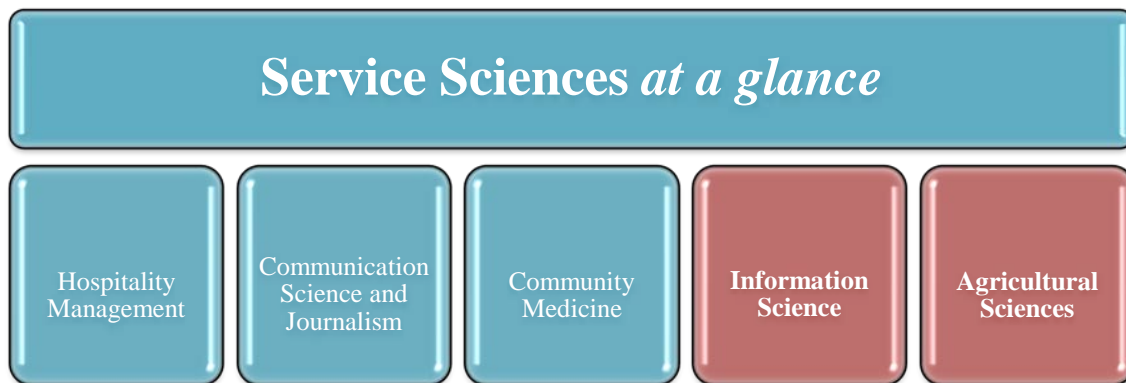


Fig.3 Service science apart from information science at a glance

V. AGRICULTURAL INFORMATICS AND FEATURES

Agricultural Informatics is an interdisciplinary and emerging subject mainly deals with various features and natures, among them, few important areas under

A. Interdisciplinary

Agricultural Informatics in an interdisciplinary field; and majorly combines with Agricultural Sciences (with the allied areas like horticulture, veterinary sciences, ecology, geography, anthropology). And the other hand with Information Sciences (is broader than other areas viz. Computer Science, Computer Engineering Computer

Applications, IT, Information Systems). The branch Agricultural Informatics is thus technological, social, ecological, and as it helps in developing the business promotion so also hold the nature of Managerial and Commercial, etc [19], [23], [32].

B. Information Centric

Agricultural Informatics or Agricultural Information Science or Agricultural Information Technology—whatever the name is powered by the information or similar contents like knowledge, data etc. Initially only Agricultural Documentation was practiced in agro organizations; mainly for post-production and official activities but with the introduction of the Agricultural Informatics the pre-production works become easy and useful as well.

C. Tool Based

Agricultural Informatics depends on various tools from the Engineering Sciences (mainly from general farming and Agricultural Engineering) and tools of Management Science for better and healthy Agricultural practices and further activities.

D. Technology Depended

Agricultural Informatics is full of technologies viz. computational technologies and information technologies with its components viz. database technologies, networking technologies, web technologies, and multimedia technologies. Additionally, the latest and futuristic information technology becomes also important in Agricultural Informatics practices.

E. Changing Nature & Nomenclature

Agricultural Informatics is emerging and changing rapidly with fulfilment of its valuable aim and objective for making advanced agricultural systems. The changing nature of Agro systems led many other nomenclatures viz.—

1. Agricultural Information Technology,
2. Agricultural Information Science and Technology,
3. Agricultural Information Systems
4. Agricultural Information Management
5. Agricultural Documentation
6. Smart Agriculture
7. Digital Agriculture etc.

F. Emerging Technology Focused

Due to the changing nature, Agro Informatics becomes associated with other emerging subjects and getting more applied in nature. As a result, various other components become an integral part of Agro Informatics and among these few important are includes Cloud Computing and Technologies, Robotics and AI, Green Computing and Systems, Human Computer Interactions, Usability

Engineering, Big Data Management, Data Analytics, etc [20], [22], [29].

G. Manpower and Skill Centric

Agricultural Informatics holds various fields, technologies, emerging technologies, management techniques, etc. Thus, it is essential that the professionals engaged in Agricultural Informatics should be updated and skilful from time to time. Hence proper manpower is highly solicited.

H. Societal

Agricultural Informatics holds a tremendous role in societal development and promotion. First, both the branches from which Agricultural Informatics was originated treated as socially touched fields (i.e. Agriculture and Informatics). And the core aim of the Agricultural Informatics is also developing Agricultural systems, which ultimately help in societal development and promotion in different means.

I. Ecological & Sustainable

Agricultural Informatics deals with ecology; not only indirectly but also directly in a different context. Agricultural Informatics is responsible for productive development, better healthy and natural farm management, and betterment in cultivators. The field of Agricultural Informatics helps in ecological development.

J. Economical & Development Centric

Most of the nations, to date, agriculture depended and till around the world, a major occupation lies in Agriculture and allied activities. As Agricultural Informatics helps in pre-production and postproduction of Agricultural systems including marketing, Agro business, manpower and job development so that the field strongly helps in economical and development activities by different sorts.

In agricultural Informatics manpower development is a major requirement in the response of healthy Agricultural practice of the branch. However proper awareness, governmental supports, etc are required for healthy development and promotion of the Agricultural Informatics systems.

VI. FUNCTIONS OF AGRO INFORMATICS

Agriculture is the valuable aspects and concern in society and agriculture plays a leading role for the economic growth of the country or territory. It is the concern in development; and till now a good amount of people are associated with the profession of agriculture. Among these professions, few are directly associated with agriculture or cultivation, whereas few are connected indirectly. In developed nations Agricultural Informatics is an important tool dedicated to ICT based agriculture; however, in recent past many developing, and few undeveloped countries also imparted

Agricultural Informatics into their operations. Agricultural Informatics is also helpful in employment and job creation. It is a fact that millions of farmers with very minimum skills and unable to do the operation of ICT in Agriculture, however with proper strategy this is can be brought out. The farming and cultivation are concerned with heat, cold, flood, drought, insect, pest infestations, disease, weather, etc in most of the cases Agricultural Informatics can be a great tool. Even in food habits, nutritional aspects, global business, technological systems, ecological aspects, etc, the Agricultural Informatics may be a good tool [21], [25], [28]. IT in agriculture helps in efficiency, reduction of cost, reduction of resources, automation, etc. Agricultural Informatics can bring with the following solutions in terms of development.

Increased Efficiency is an important concern of Agricultural Informatics and helps in monitoring of Agricultural products by this prediction is become and which will help in decision making. AI & Expert Systems of Information Technology helps in healthy and enhanced demand-based irrigation, fertilizing, automated harvesting, weather and climate and prediction, etc; and these are helpful in healthy Agricultural operation.

Expansion of the Agricultural sector becomes possible with healthy initiation of the Agricultural Informatics. In the recent past with better practice of Agricultural Informatics, the Smart closed-cycle agricultural systems are growing and this is helping not only in Expansion but also in Resource Reducing and for this optimizing play a leading role with the water, energy, land, etc. In both the context of Agricultural Informatics practice, the various sensors play a lead role with limited resources.

In case of Cleaning and Purity also the practice of Agricultural Informatics become useful in managing of pesticides, better uses in fertilizers, etc, the following will help in future operations

1. With Agricultural Informatics the precision farming (water and energy, etc) become possible easily
2. The cleaning and green strategy with greener farming can be easily possible to bring with the help of Agricultural Informatics
3. Moreover, in the promotion of the Organic Agriculture, applications of Agro Informatics played a leading role in respect of conventional agricultural methods.

Agricultural Informatics helps in Healthy and Quicker Agricultural Systems with the help of real-time monitoring and in this regard following play a leading role

1. Cloud Computing and Technologies,
2. Robotics and AI,
3. Human Computer Interactions,
4. Big Data Management, etc

Hence with such supports, cultivators can quickly decide in agriculture especially in pre-cultivation viz. weather, humidity. Health of crop, soil may also be possible to know by the IoT based applications in Agricultural Informatics.

Quality Production is thus possible with proper Agricultural Informatics practice and in this context aerial drone monitoring important. In farm mapping, analysis of the conditions of the crops with quality is possible to know by proper Agricultural Informatics practice. Thus, Agricultural Informatics practice finally helps in bringing of quality foods products, plants, corps, etc [18], [31].

With Agricultural Informatics practice it is possible to know about the temperature and weather including the rainfall, humidity, wind condition including speed, pest infestation, soil condition, etc. Ultimately it will bring in automated farming including the techniques and technology is possible with Agro Informatics. Furthermore, the activities and functions of Agricultural Informatics are provided in Table: 1 herewith.

Apart from these, Agricultural Informatics also indirectly helps in Energy management of the electronic products such as bulbs, televisions, network devices, IoT and Analytics devices, drone management, switches, power outlets, etc. Here one of the emerging tools of bulbs, televisions IoT is helpful. Thus, ultimately it helps in more activities in environmental protection as well viz.

1. Environmental protection by the monitoring air or water quality with different tools viz. drones.
2. With the uses of Agricultural Informatics tools, the movements of wildlife and other animals become possible to gather.
3. Disaster management is directly and indirectly possible to now with the help of Agricultural Informatics based IoT systems.

Agricultural Informatics thus helps in a different kind of cultivation including large scale agricultural practices and results following benefits as a whole

1. Healthy, Improved and Efficient Input as well Output systems of the Agriculture
2. Intelligent Agricultural Practices
3. Integrating and facilitating Agricultural Business
4. Agro Marketing including supply chain management, etc
5. Improved and Mature Postproduction activities in Agriculture.
6. Good food security systems as far as Agriculture are concerned.
7. Improved Agricultural systems with Climate systems and development, etc.

TABLE I FEW IMPORTANT FUNCTIONS OF MODERN AGRICULTURAL INFORMATICS IN BRINGING DIGITAL AGRICULTURE

<p>Agricultural Informatics Vis-à-Vis Weather, Climate</p>	<p>Weather is an important aspect in farming and it ultimately results in quantity and quality of crop production including the post crop production activities. With modern Agro Informatics practice viz. IoT supported sensors right weather can be learned including detecting of real-time weather such as humidity, rainfall, temperature. Thus, with better Agricultural Informatics practice their physical presence becomes minor and here cultivators can decide accordingly.</p>
<p>Agricultural Informatics Vis-à-Vis Precision Cultivation</p>	<p>Precision Agriculture and cultivation is one of the emerging and gives very efficient precision. Here Agricultural Informatics will play an important role especially in soli condition analysis, livestock monitoring, field stud, financial activities viz. inventory and budget monitoring, transportation management. Here IoT, Data Analytics will be important to get and analyzed data by the sensors. Hence quick decisions, intelligent performance is helpful in precision agriculture and cultivations.</p>
<p>Agricultural Informatics Vis-à-Vis Remote Cultivation</p>	<p>Technological advancements help in better agricultural operations and as far as remote cultivation is concerned here agricultural drones play a leading role. With such kind of tools, the Ground as well as Aerial view becomes easy. And this will ultimately help in analyzing crop health and its monitoring even including spraying. Hence it reduced less field work. The real time data and videos is possible with remote based drone technology. Here both, thermal or multispectral sensors can be useful so helping in the improvement of irrigation also. The smart drones reduce environmental impact and also a reduction in chemical, etc.</p>
<p>Agricultural Informatics Vis-à-Vis Livestock Management</p>	<p>With proper and modern Agricultural Informatics practice such as with wireless IoT, etc data collection on location, well-being, etc become possible. Even with this, animal management (such as cows, sheep, pig, etc) becomes possible. The postproduction agriculture is possible to analyze with healthy Agricultural Informatics. The post agricultural activities including in marketing of agro products, supply chain management, budget, inventory, etc become easily possible with healthy and modern techno enable Agricultural Informatics practice.</p>

VII. STAKEHOLDERS OF THE STUDY OF AGRICULTURAL INFORMATION SCIENCES

Agricultural Informatics is an important and emerging Science and Technology; it is also holding the nature of interdisciplinary studies. Further, it holds the nature of social sciences due to its social role and management sciences knowledge as well for better ago practices and postproduction activities. Various subjects viz. IT, Computing, Informatics, Agriculture, Environmental Sciences, etc responsible for developing healthy agro based systems. Due to the nature, scope, diversity and periphery, the Agricultural Informatics needs following

1. Accurate, scientific amount of skilling on Agro, Ecology, IT and Management at-least.
2. Field knowledge of Agriculture Practice and Observation skills.
3. Communication skills for interpretation.
4. Entrepreneurship skills in Agriculture and IT, both the fields.

5. Leadership and Administrative qualities, etc [16], [33]

Agricultural Informatics as a branch of study and practice emerging rapidly and earlier there was no subject on Agricultural Informatics but the Agricultural data management, uses of basic Computers was common. Gradually, Agricultural Informatics becomes a field of study now. However, previously the subject Agricultural Documentation was started slightly. Agricultural Informatics is also available with various other emerging names and nomenclatures and among these few important are mentioned bellows (with a basic explanation of the field as per nature of the subjects).

A. Agricultural Information Systems

This is an important subject and dedicated in business and management activities of Agricultural aspects with the technologies as far as the nature of the domain ‘Information Systems’ are concerned. Information Systems in concentrated on IT applications in business and commercial

areas and thus Agricultural Information Systems should hold the same nature.

B. Agricultural Information Technology

Agricultural Information Technology may simply denote the subject responsible for the applications of Information Technology (database technologies, networking technologies, web technologies, multimedia technologies, etc) in agriculture and allied sciences. So, this field may be called as smaller than Agricultural Informatics.

C. Agricultural Information Science

Agricultural Information Science can be considered as equal to the Agricultural Informatics, however scientifically and as per expert 'Informatics' is mainly with practice whereas 'Information Science' mainly a field of study first and secondly as a practicing field. However, both Agricultural Informatics and Agricultural Information Science can be called equal in a general context.

D. Smart Agriculture

The latest nomenclature from the Agricultural Informatics may be considered as Smart Agriculture. The term Smart Agriculture denotes, it is responsible for the modern, advanced agricultural practice with the help of various tools, technology, methods, principles etc. Hence, Smart Agriculture can be considered as beyond Agricultural Informatics that can be smart in nature may be more than IT enabled.

E. Digital Agriculture

Like Smart Agriculture, this is also a field of practicing in Agriculture and allied areas. Even this nomenclature in recently widely used in academics, industries of agro related areas, governmental bodies, etc. Among the educational providers in this field, most popular are include University of Edinburg, UK.

F. ICT in Agriculture etc

ICT in Agriculture can be considered as another nomenclature within Agricultural Informatics and this is mainly concentrated on IT applications in the Agriculture and allied fields with special focus on Networking and Communication Technologies in different sections, etc [15], [19], [30].

Hence, Agricultural Informatics as a branch gaining rapidly due to its role in diverse areas viz. pre-production in cultivation, post production of Agricultural systems and in this context apart from traditional information technologies most emerging are Cloud computing, Big data Management/ Data Analytics, Artificial intelligence and expert system, Geographic Information System, Internet of things, etc. As a field of Agricultural Informatics above may

be considered as stakeholders but in general, in addition to above, some others are also considerable as a stakeholder viz. Contents or Information, Technologies, People and Agro Objects (Refer fig: for details).

VIII. AGRICULTURAL INFORMATICS, ACADEMIC PROGRAMS AND MANPOWER

Agricultural Informatics is responsible for the advancement and development of agriculture by its various principles, tools and methods towards healthy cultivation, pre and post agricultural activities which includes supply chain management, marketing management, and business promotion in Agriculture etc. However, for doing such activities proper and skilled manpower are required and such are maybe the farmers or may not be. The Agricultural Informatics ultimately helps in following as well

1. Agricultural Industries and Institutions including Chamber of Commerce's
2. Agricultural research and extension services,
3. Scientific organizations in Agro development
4. Educational and Research baaed Institutes in Agriculture or allied.
5. Sustainable Agricultural development and promotion

Internationally many organizations as well as educational institutes including the training centers are established and this trend is growing rapidly. Even in better management and development of agricultural activities Agricultural Informatics is important and required. In allied fields such as in horticulture, ecology, forestry, geography as well this field becomes important is required as per the time need. The Agro Informatics professionals can do the technological and computational activities in a more scientific manner and meaningful way. For the development of Smarter Agricultural systems in many modern and developed nations, Agricultural Informatics becomes a field of study with various UG, PG and Research Programs. The design and development of healthy Agricultural systems in many ways depend on such skilled manpower. In the line of developed nations, many other developing nations have started educational programs on Agricultural Informatics or in allied nomenclature. As far as India is concerned, some of the bellow mentioned institutes started programs on Agricultural Informatics or allied emerging fields

1. Tamil Nadu Agricultural University, located in Coimbatore, Tamil Nadu
2. Shobhit University, located in Meerut, Uttar Pradesh
3. Rai University, Ahmedabad, Gujarat
4. Anand Agricultural University, located in Gujarat
5. Integral University, located in Lucknow, Uttar Pradesh

Due to interdisciplinary nature, the field consists of various course components viz. Basics of the Agricultural Science & Management, Fundamentals of Engineering Sciences, Many components of Information Technology and

Computing. Due to the nature of society, Agricultural Informatics also deals with Social Science & Environment as well. Thus, for promotion of the ICT in Agriculture that will lead the Smart Agriculture; Agricultural Informatics will play a leading role. In India, some of the universities have started educational programs (engineering) on Agricultural Informatics and few of them are mentioned in the table II.

TABLE II DEPICTED THE AVAILABLE PROGRAMS ON AGRO INFORMATICS IN FEW INSTITUTES

Universities/ Institutes	Programs
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India	B Tech Agricultural Information Technology
Centre for Agricultural Informatics and E Governance Research Studies Shobhit University, Meerut, UP, India	M Tech Agricultural Informatics
Anand Agricultural University, Gujarat, India	M Tech Agricultural Information Technology

Whereas, further Agricultural Informatics is also applicable in Science and similar fields viz. Dhirubhai Ambani Institute of Information and Communication Technology (A Deemed University), Gujarat, India with MSc-IT in Agriculture & Rural Development program. Agricultural Informatics is helpful in enhancing and emerging the productivity and in agriculture in different sorts and means. Therefore, Agricultural Informatics should be offered in different educational programs (refer table: 3) for the ultimate benefits of the following.

TABLE III POSSIBLE ACADEMIC PROGRAMS ON AGRICULTURAL INFORMATICS IN DIFFERENT LEVEL AND STREAMS

Streams	Programs
Engineering by Coursework	B Tech/BE/M Tech/ME
Engineering by Research Work	B Tech/BE/M Tech/ME
Sciences by Coursework	BSc/MSc
Sciences by Research Work	BS/MS
Management by Coursework	BBA/MBA
Commerce by Research Work	B.Com/M.Com
Environment and Ecology	BA/MA-Environment e.g. (Agricultural Informatics)

1. For the comprehensive knowledge and understanding and needs on this emerging field.
2. To learn about the practical and field based on IT integration in Agriculture including the use of sensor

systems for the monitor the agricultural systems and environment.

3. To design, development and management, manipulating Agricultural Database and their better operations.
4. To get the conceptual understanding and knowledge of the allied subject's viz. horticulture ecology, forestry, etc to reach beyond the goal.
5. Agricultural Informatics is helping in gaining of systematic skills, meaningful outcomes for smarter Agricultural systems including pre and post agro related works.
6. Agricultural Informatics is required to build healthy industries and business in Agriculture and allied areas [5], [23], [32].

IX. SUGGESTIONS

Agricultural Informatics is important for various reasons including cultivation in the field, farming with the animals, and marketing of agricultural products i.e. the post agricultural activities. The following points are essential for developing Agricultural systems for better sustainability.

1. It needs a higher amount of investment including the technologies regarding its initial set, implementation, and post installation services.
2. In Agricultural Informatics many activities are there viz. designing, development of systems, tools, fields, and products and in all such cases it is required that all the manpower should be skilled, developed, and knowledgeable. Hence proper educational opportunities need to bring in.
3. Agricultural Informatics is connectivity based and electronic in nature; hence proper and healthy and continuous internet as well electricity services are highly required for the same.
4. Manpower availability and development; in both there are many issues and challenges. Hence important programs on this area are important with various emerging specializations viz. IoT and Agriculture, Cloud and Agriculture, Big Data and Agriculture, Robotics and AI in Agriculture, etc.
5. In other similar nomenclature such as in such as in Agro ICT, Agricultural Information Technology, Smart Agriculture, Digital Agriculture, etc the educational and research programs may be started in the future.
6. Industrial tie-ups, collaboration with the Agro Industries with the Agricultural farms, Agricultural Companies, IT Companies are highly required.
7. IoT, Cloud Computing, Data Analytics, HCI, Robotics and Cloud are very important in bringing of good agricultural practices for the ultimate development of the smarter Agricultural Systems.

X. CONCLUSION

Worldwide the educational systems become changing and modern subjects, areas have been started internationally. The promotion of interdisciplinary knowledge is noticeable in the recent past. Sustainable agricultural systems have been initiated in different countries and towards in healthy Agricultural systems. In this context apart from applications of Management, proper rules, and regulations the most advanced Agricultural Informatics will play an important role. Emerging technologies viz. IoT, Big Data, Cloud, etc are required in modern agriculture system practice. With this, the existing water, climate, soil, crop, plants, animals are possible to get with humidity, temperature, etc. Agro Informatics also needs proper and required manpower development with solid planning and educational policies. Moreover, proper academic and industrial collaborations are also needed for the same. Here integration of different kind of Agricultural establishments are also very much required such as firms, trusts, companies, etc in promotion of Smart Agriculture, Sustainable Development, Modern Agricultural Development in many contexts.

REFERENCES

- [1] Abbasi, A. Z., Islam, N., & Shaikh, Z. A. (2014). A review of wireless sensors and networks' applications in agriculture. *Computer Standards & Interfaces*, 36(2), 263-270.
- [2] Adão, T., Hruška, J., Pádua, L., Bessa, J., Peres, E., Morais, R., & Sousa, J. J. (2017). Hyperspectral imaging: A review on UAV-based sensors, data processing and applications for agriculture and forestry. *Remote Sensing*, 9(11), 1110.
- [3] Adetunji, K. E., & Joseph, M. K. (2018, August). 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)* (4849-4854). IEEE.
- [4] Ahmad, T., Ahmad, S., & Jamshed, M. (2015, October). A knowledge based Indian agriculture: With cloud ERP arrangement. In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)* (333-340). IEEE.
- [5] Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision support systems*, 54(1), 510-520.
- [6] Babu, S. M., Lakshmi, A. J., & Rao, B. T. (2015, April). A study on cloud based Internet of Things: CloudIoT. In *2015 global conference on communication technologies (GCCT)* (60-65). IEEE.
- [7] Balamurugan, S., Divyabharathi, N., Jayashruthi, K., Bowiya, M., Shermey, R. P., & Shanker, R. (2016). Internet of agriculture: Applying IoT to improve food and farming technology. *International Research Journal of Engineering and Technology (IRJET)*, 3(10), 713-719.
- [8] Bauchhage, C., & Kersting, K. (2013). Data mining and pattern recognition in agriculture. *KI-Künstliche Intelligenz*, 27(4), 313-324.
- [9] Channe, H., Kothari, S., & Kadam, D. (2015). Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *Int. J. Computer Technology & Applications*, 6(3), 374-382.
- [10] Gill, S. S., Chana, I., & Buyya, R. (2017). IoT based agriculture as a cloud and big data service: the beginning of digital India. *Journal of Organizational and End User Computing (JOEUC)*, 29(4), 1-23.
- [11] Gómez-Chabla, R., Real-Avilés, K., Morán, C., Grijalva, P., & Recalde, T. (2019, January). IoT Applications in Agriculture: A Systematic Literature Review. In *2nd International Conference on ICTs in Agronomy and Environment* (68-76). Springer, Cham.
- [12] Goraya, M. S., & Kaur, H. (2015). Cloud computing in agriculture. *HCTL Open International Journal of Technology Innovations and Research (IJTIR)*, 16, 2321-1814.
- [13] Guardo, E., Di Stefano, A., La Corte, A., Sapienza, M., & Scatà, M. (2018). A fog computing-based iot framework for precision agriculture. *Journal of Internet Technology*, 19(5), 1401-1411.
- [14] Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2020). Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, 219, 179-194.
- [15] Kajol, R., & Akshay, K. K. (2018). Automated Agricultural Field Analysis and Monitoring System Using IOT. *International Journal of Information Engineering and Electronic Business*, 11(2), 17.
- [16] Khattab, A., Abdelgawad, A., & Yelmarthi, K. (2016, December). Design and implementation of a cloud-based IoT scheme for precision agriculture. In *2016 28th International Conference on Microelectronics (ICM)* (201-204). IEEE.
- [17] Liu, S., Guo, L., Webb, H., Ya, X., & Chang, X. (2019). Internet of Things monitoring system of modern eco-agriculture based on cloud computing. *IEEE Access*, 7, 37050-37058.
- [18] Manos, B., Polman, N., & Viaggi, D. (2011). *Agricultural and environmental informatics, governance and management: Emerging research applications*. Z. Andreopoulou (Ed.). IGI Global (701 E. Chocolate Avenue, Hershey, Pennsylvania, 17033, USA).
- [19] Muangprathub, J., Boonnarn, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019). IoT and agriculture data analysis for smart farm. *Computers and electronics in agriculture*, 156, 467-474.
- [20] Na, A., & Isaac, W. (2016, January). Developing a human-centric agricultural model in the IoT environment. In *2016 International Conference on Internet of Things and Applications (IOTA)* (292-297). IEEE.
- [21] Nandyala, C. S., & Kim, H. K. (2016). Green IoT agriculture and healthcare application (GAHA). *International Journal of Smart Home*, 10(4), 289-300.
- [22] Nayyar, A., & Puri, V. (2016). Smart farming: IoT based smart sensors agriculture stick for live temperature and moisture monitoring using Arduino, cloud computing & solar technology. In *Proc. of The International Conference on Communication and Computing Systems (ICCCS-2016)* (pp. 9781315364094-121).
- [23] Ojha, T., Misra, S., & Raghuvanshi, N. S. (2015). Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. *Computers and Electronics in Agriculture*, 118, 66-84.
- [24] Othman, M. F., & Shazali, K. (2012). Wireless sensor network applications: A study in environment monitoring system. *Procedia Engineering*, 41, 1204-1210.
- [25] Ozdogan, B., Gacar, A., & Aktas, H. (2017). Digital agriculture practices in the context of agriculture 4.0. *Journal of Economics Finance and Accounting*, 4(2), 186-193.
- [26] Paul, Prantosh Kumar Minakshi Ghosh, Dipak Chatterjee. (2014). Information Systems & Networks (ISN): Emphasizing Agricultural Information Networks with a case Study of AGRIS. *Scholars Journal of Agriculture and Veterinary Sciences*. 1(1), 38-41.
- [27] Paul, Prantosh Kumar(2013).Information and Knowledge Requirement for Farming and Agriculture Domain. *International Journal of Soft Computing Bio Informatics* 4 (2), 80-84.

- [28] Paul, Prantosh Kumar *et.al.* (2015). Agricultural Problems in India requiring solution through Agricultural Information Systems: Problems and Prospects in Developing Countries. *International Journal of Information Science and Computing*, 2(1), 33-40.
- [29] Paul, Prantosh Kumar *et.al.* (2016). Cloud Computing and Virtualization in Agricultural Space: A Knowledge Survey. *Palgo Journal of Agriculture*, 4(2), 202-206.
- [30] Paul, Prantosh Kumar *et.al.* (2015). 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*. 5 (2), 155-161.
- [31] Rezník, T., Charvát, K., Lukas, V., Charvát Jr, K., Horáková, Š., & Kepka, M. (2015, September). Open data model for (precision) agriculture applications and agricultural pollution monitoring. In *EnviroInfo and ICT for Sustainability 2015*. Atlantis Press.
- [32] TongKe, F. (2013). Smart agriculture based on cloud computing and IOT. *Journal of Convergence Information Technology*, 8(2), 210-216.
- [33] Tsekouropoulos, G., Andreopoulou, Z., Koliouka, C., Koutroumanidis, T., & Batzios, C. (2013). Internet functions in marketing: multicriteria ranking of agricultural SMEs websites in Greece. *Agrárinformatika/journal of agricultural informatics*, 4(2), 22-36.
- [34] Zamora-Izquierdo, M. A., Santa, J., Martínez, J. A., Martínez, V., & Skarmeta, A. F. (2019). Smart farming IoT platform based on edge and cloud computing. *Biosystems engineering*, 177, 4-17.