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REVIEW PAPER

Agricultural 4.0: The Root for Agricultural Transformation— *A Scientific Review*

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ABSTRACT

Agriculture 4.0 is the latest development in Agricultural sector using technology, in the line of industrial revolution this fourth agriculture revolution has been arrived where digital technologies dedicated for advanced, smarter, environmental friendly agricultural systems. As far as enhancement in sustainability, technological utilizations are concerned with effective farm methods Agriculture 4/.0 promises new hope. The basic philosophy of Agricultural 4.0 integrates various digitalization, automation systems including artificial intelligence, machine learning and deep learning, robots, big data and analytics, Internet of Things, cloud computing, augmented reality, and so on. As industry transforming as well as upgrading day by day therefore agriculture sector is also growing rapidly. Industry development is impacted without expansion of agricultural growth. Agriculture 4.0 is the advance and transformed agriculture system in association with state-of-art technology. Technological support makes the agricultural system healthy and advanced. Various technologies are involved in progress of agriculture 4.0. Technology involve in development of agriculture sector in connection with improvement of various areas of agriculture such as farming process, food supply chain, monitoring of weather condition and other areas. This paper is a theoretical and conceptual work dedicated in finding Agriculture 4.0 including features, functions, impact and role in advancing agricultural sector.

Keywords: Agro Informatics, Digital Agriculture, Agriculture 4.0 Smart Agriculture, Sustainability, Digitalization

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The word Agriculture 4.0 term first coined in The World Government Summit in a report named as *Agriculture 4.0 – the Future of Farming Technology,* this event was conducted in collaboration with Oliver Wyman. This report suggested about four aspects in order to agricultural development viz,—

- Demographics,
- Scarcity of natural resources,
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According to the report the demand regarding food supply will be 2050 and therefore it is the need of the hour to produce more foods and it has predicted about the growth of producing 70 food. It has been noted that about 800 million people internationally are victim of food hunger, and thus in regard to food scarcity and hunger management in coming decades Agricultural 4.0 considered as impactful and required using various technologies[11],[35].

In advancing Agriculture 4.0 *Remote Sensing* and *GIS* may be considered as valuable in regard to getting data on soil moisture, crop health, and crop yields. As far as monitoring large areas are concerned remote sensing specially GIS supported matters like satellite imagery and ground-based sensors are suitable in getting data on crops and soil. Some other areas and tools like *Drones* also considered as impactful in advancing agriculture and monitoring crop, remote survey of the land, pesticide spraying, collecting various real-time data including growth, issues and problems. As a whole other geo-technologies are dedicated in developing the maps, spatial data analysis, better land management, advancing irrigation systems, soil development, etc. Artificial Intelligence is dedicated in more automation and developing irrigation system, it is dedicated in predicting diseases, managing resource and crop management, agricultural marketing, agricultural supply chain management, etc.

Machine learning and Deep Learning is also important in collecting datasets and to predicts various aspects in regard to crop yields, therefore with ML and DL farmers are able in decision making regarding time of plantation, fertilization time, managing pest control, thus all these are dedicated in enhancing productivity[10],[34],[35]. In addition to these IoT (Internet of Things) is dedicated in connecting the devices with the internet and similar systems and to manage agricultural devices and systems. Gathered data and large number of regular data effectively possible to manage using *Data Analytics* based systems. Accessibility of such large, generated data and infrastructure sharing become possible using *Cloud Computing*. Thus, Agriculture 4.0 is dedicated in developing technology supported agricultural systems and mechanism.

OBJECTIVE

The paper titled 'Agricultural 4.0: The root for Agricultural Transformation— *A Scientific Review'* is focused on following aim and objective (but not limited to)—

- ❒ To know about the basic of Agricultural 4.0 including features and characteristics in brief manner.
- ❒ To gather the knowledge regarding impact, role and significance of Agriculture 4.0 in advancing Agricultural sector more developed and advanced.
- ❒ To learn about the existing technologies, current progress of Agricultural 4.0 from existing publications and research work.
- ❒ To learn about the technologies involved in Agriculture 4.0 and gather a basic knowledge in Agricultural Informatics.
- ❒ To learn a basic on challenges, issues and concern in Agricultural 4.0 in order to develop Agricultural sector more systematic and advanced.

METHODS

As far as 'Agricultural 4.0: The root for Agricultural Transformation— *A Scientific Review'* titled paper is concerned existing research works have been consulted, analyzed and reported in this paper. In addition to journal paper few doctoral thesis and newspaper reports also been studied and reported here in this work. Since Agricultural 4.0 is based on latest information technologies therefore the industrial players and company websites are analyzed in regard to conducting this work.

REVIEW OF LITERATURE

A major work related to Agricultural Informatics has been already conducted by leading researcher worldwide, and regarding Agricultural 4.0 related works few are depicted as under—

Ayaz, M. *et al.* (2019)[4] analysed the rise of IoT-based technology has made the agricultural sector more data-centric, accurate, and intelligent. This article highlights the possibilities and problems that come with using wireless sensors and the IOT in agriculture. With an emphasis on particular applications including soil preparation, crop status, irrigation, and insect and pest detection, IoT devices and communication methods are examined. Growers benefit from the technology at every step of the agricultural cycle, from planting to harvesting, packaging, and shipping. For agricultural production optimization and crop observation, unmanned aerial vehicles are also taken into consideration. Potential research difficulties are mentioned together with current and future developments of IoT in agriculture.

Klerkx, L. and Rose, D. (2020)[21] evaluated the promise of cutting-edge technology like blockchain, artificial intelligence, and machine learning to revolutionize agricultural and food systems is highlighted by a report on agricultural 4.0. They contend that more attention should be paid to their impact on inclusion and exclusion, how they relate to transition pathways, and whether or not the paths of transitions may be altered.

Klerkx, L., Jakku, E. and Labarthe, P. (2019)[22] investigated the role of digital agriculture in relation to supply chains, food networks, and agricultural production methods. The topic of digitalization in

agriculture has received a lot of attention, but very little in the way of critical evaluation. The research found five groupings of related themes in the literature on digitalizing agricultural production systems and value chains: digitalization and agricultural knowledge and innovation systems (AKIS), digitalization and the adoption and adaptation of digital technology on farms, the effects of digitalization on farmer identity and skills, and economics and management of digitalized agricultural production systems. Pathways for agricultural transitions made possible by digital technology, policy processes for digital agriculture, conceptualizations of the socio-cyber-physical-ecological systems of digital agriculture, and the global geography of the field's growth were the four new clusters identified by the study, which also brought attention to innovative approaches to the ethical regulation of digital agriculture.

Lezoche, M. (2020) Lezoche *et al.* (2020)[27] presented on "Agriculture 4.0" in reaction to the 1.0 and 2.0 phases of the industrial revolution. Through the use of digital technology and interoperability procedures, this approach allowed for the transfer of information in real time. Maintaining intricate, networked systems that are effectively connected and arranged proved difficult, particularly in light of the changing demands of supply chain stakeholders. With its distinct features, agriculture has embraced digital technology. Examples of this include sensors and drones for data collecting on weather, specialization, crop and animal activities, and the whole farm life cycle, as well as electronic controls for agricultural equipment. Improving the performance of the agricultural supply chain remained a difficulty, however. Agriculture 4.0 is a development of Industry 4.0, which examined performance and behaviour in this field. The unanswered issue is how Agriculture 4.0 may improve decision-making in the supply chain or enable farmers to make efficient choices based on factual data, therefore saving time. In order to ascertain the future directions of the agri-food industry, this study examined more than a hundred articles on cutting-edge technology and supply chain strategies.

Liu, Y., Ma, X., Shu, L., Hancke, G.P. and Abu-Mahfouz, A.M. (2020)[28] examined the evolution of the agriculture industry from conventional to mechanized and precision farming, and concluded that Industry 4.0 will bring about a total transition. They explored five cutting-edge technologies for Agriculture 4.0: robotics, artificial intelligence, big data analytics, blockchain, and the Internet of Things. They also looked at the situation of industrial agriculture today, agri-food supply networks, and production patterns.

Ray, P.P. (2017)[39] revealed a new avenue for creative study in the field of agriculture with the introduction of the IoT. IoT is still in its infancy, thus a lot more testing was required before it could be extensively used for a range of agricultural applications. This report analyzed a number of possible Internet of Things applications as well as the particular problems and difficulties related to IoT adoption for better farming. The gadgets and wireless communication technologies related to IoT in farming and agricultural applications were thoroughly examined in order to concentrate on the particular needs. Sensor-enabled Internet of Things systems that offered smart and intelligent services for smart agriculture were the subject of investigations. A range of case studies were shown to examine the current IoT-based solutions that have been adopted by different companies and people, arranged based on their deployment specifications. Related challenges with these solutions were also noted, as well as areas for development and the future course of IoT activity.

Rose, D.C. and Chilvers, J. (2018)[40] studied artificial intelligence (AI), robots, and the Internet of Things have all revolutionized agriculture with their ability to increase production and reduce environmental impact. On the other hand, the societal consequences of these technologies worry some agricultural professionals. The opinions of agricultural communities and larger society have been called into question

by scholars, technological corporations, funders, and policymakers. While responsible innovation has not received much attention in the agricultural sector, several recent publications propose that this fourth agricultural revolution should include some of the concept's essential elements. Though frameworks should be put to the test in real-world settings to help influence innovation trajectories, concepts of responsible innovation need be further refined to make them resilient and relevant for emerging agri-tech. An expanded definition of inclusion, a systematic approach, and more extensive testing of frameworks in real-world settings are all necessary components of a more thorough framework for responsible innovation in sustainable agriculture.

Shafi, U. *et al.* (2019)[43] studied the agricultural industry could undergo a change thanks to the IoT, which might make it more intelligent and need less labor from humans. Automation in agriculture is mostly being driven by wireless sensor networks (WSN) and precision agriculture (PA). PA retrieves actual data from field sensors and employs sensors and software to maximize agricultural output and sustainability. Satellite or aircraft platforms provide high-resolution photos of crops, which are analyzed to inform decision-making in the future. This study examines wireless communication technology, sensors, and nodes utilized in near- and far-reaching agricultural sensor networks to evaluate environmental behavior. To show how a WSN-based PA system is implemented, a case study is given. Two modules comprise the proposed Internet of Things (IoT) smart crop health monitoring solution: a low-altitude remote sensing platform for multi-spectral images classification and a wireless sensor network-based system for real-time crop health status monitoring.

Sinha, B.B. and Dhanalakshmi, R. (2022)[44] Analyzed as a developing paradigm, the IoT aimed to link various smart physical components for multi-domain modernization. Many IoT-based frameworks were established to autonomously manage and monitor agricultural areas with minimum human interaction. This study included a thorough analysis of the key elements, emerging technologies, security concerns, difficulties, and potential future directions in the field of agriculture. The article included a detailed summary on recent advances. This survey was designed to assist future researchers in identifying pertinent Internet of Things challenges and selecting appropriate technologies depending on application needs. Additionally, the importance of data analytics and the Internet of Things for smart agriculture was emphasized.

Zambon, I. *et al.* (2019)[46] in order to comprehend the difficulties small and medium-sized enterprises (SMEs) have in adopting the 4.0 revolution, a research examined the farm supply chain and Industry 4.0 standards. For SMEs, the creative processes may be challenging, even with the advantages of Industry 4.0 for bigger businesses. As a way to encourage SMEs to invest in these technologies and become more competitive in the market, the report recommends that policymakers propose concepts and suggestions.

Zhai, Z. *et al.* (2020)[47] aimed to increase production, allocate resources wisely, adjust to climate change, and reduce food waste, agriculture 4.0 is the fourth generation of agricultural technology. This technology collects and analyses agricultural data using Internet and sophisticated computer systems, empowering farmers to make more profitable choices. In Agriculture 4.0, food waste reduction, water resource management, agricultural mission planning, and climate change adaptation are the main topics of this article's investigation into future challenges with employing agricultural decision support systems. A thorough review of the literature was done on thirteen different decision support systems, looking at things like usability, scalability, accessibility, and interoperability. Future research topics were determined and collated, along with development trends and recommended directions.

Agricultural 4.0: An Overview with Technological Integration

Economical development of the country depends on industrial growth. Agriculture is the base of the development of economy, and gives support in development of the country. Enhancement of agricultural growth expands the growth of development of the country. Nowadays, it has been observed that there is revolutionary improvement in industry sector. Technological association in agriculture 4.0 improves and develop advance the agriculture management system. Artificial Intelligence provides support to enhance the harvesting process, monitoring of diseases, and pests control in plants[32],[36],[37]. Drones are involved in agriculture to improve the farming process. Drones are applied to monitor the harvesting fields and farming process. It helps in farming to decrease the manual work by spraying water and medicines in harvesting fields. It also gives support to capture the real time data with equipped sensors to monitor the crop health, crop growth, status of soil for harvesting. Sensors used in agriculture fields to collect information about assessment of soil eligibility for farming. Sensors are also useful to know the weather condition including wind speed, appropriate temperature for farming, measurement of moisture, and spray pressure. Internet of Things is used in farming filed to gather information and help farmer for decision making by collecting the data from GPS and sensor enable drones, satellite. Internet of Things manages all the work of farming automatically and gives various supports to the farmers to improve the farming process. Vast real time data gathered during farming and crop harvesting that managed and used for decision making[5],[11],[23].

Huge agricultural data processed with big data applications and AI tools. Cloud computing gives support to store and process mammoth of agriculture data-which is not managed by traditional computing system. Agricultural robots are developed and used in farming to plant seed, observe health condition of crops, observe how the crop growing in the field, nurturing the crops. Therefore, all advance and latest technological association transformed agriculture towards agriculture 4.0 which is related and based on industry 4.0.

Advantages of Agriculture 4.0

- ❒ Agriculture 4.0 is the advance agriculture system that enhance the production of food.
- ❒ Agriculture 4.0 provides significant real time information to the farmers to improve the farming.
- ❒ Agriculture 4.0 play a role to create automated system which help farmers for farming very efficiently.
- ❒ Agriculture 4.0 gives proper information about the weather that is good for farming.
- ❒ It helps to increases the growth of economy of the country.
- ❒ It helps to make farming more accurate and perfect.
- ❒ Agriculture 4.0 has many potentialities and significance to improve the farming.

Features and Significance of Agriculture 4.0

Emerging Technology Oriented Agriculture

Emerging technologies are associated with agriculture 4.0. AI, Cloud Computing, Edge Computing, Fog Computing, IoT, Big Data, Block Chain, are the Innovative and progressive technologies associated with agriculture 4.0. All these technologies interconnected with each other in agriculture 4.0 which transform agriculture more advance. Drones, agricultural robots, remote sensing are the advanced technologies connected with agriculture 4.0. Drones and agricultural robots provides supports and reduce the manual work in farming. Therefore, advance technologies make revolutionary changes in agriculture 4.0. All the technologies are connected with development of agriculture 4.0 and make intelligent automated agricultural system[6],[9],[20].

Progressive and Advance Agriculture

In the age of agriculture 1.0, there are labours, hand held equipment, and animals are the resources for farming. Huge amount of resources are required in farming fields. Agriculture 2.0 is progressive than agriculture 1.0 because machinery equipment or resources are used in agriculture for farming. Therefore agriculture 2.0 is better than agriculture 1.0 in respect of cost reduction, time and enhancement of productivity. Agriculture 3.0 is the next progressive agriculture system where upgraded machineries and some automated machineries are used in farming. Therefore, agriculture 3.0 is better than agriculture 2.0. Nowadays, agriculture system is more advance and progressive in connection with more innovative digital technologies. Automated and intelligent system implemented with the aid of advance intelligent based emerging technologies in agriculture 4.0. Therefore, agriculture 4.0 is advance and more innovative agriculture system[1],[3],[30].

Smart and Precision Farming

Smart and precision farming is the technology dependent system where automated system imposed to make farming more accurate.

Time and Cost Reduction

Automated intelligent agriculture system helps to reduce cost of farming. It helps to reduce the cost of the labors in farming. Manual work takes more time for harvesting such as plant seeds, plucking of crops, spreading of medicine with pesticides in the fields[7],[8],[19]. Robots and drones based automated system helps to minimize manual work as well as reduction of time.

Enhancement of Productivity

Productivity increases in agriculture 4.0 by implementing the fast and automated services which involve in increasing the speed for plantation of crops and plucking of crops from the fields. The system works very fast and efficiently. It is not possible in manual work. Therefore, agriculture 4.0 extend the production of foods. This automated system gives all support to enhance productivity such as pest control, detection of diseases, monitoring of soil status, crops health condition, weather condition that helps farmer to make correct and faster decision without facing any difficulties[12],[24],[25].

Development of Economy

Robust agriculture system improves the economic growth of the country. Therefore, advancing of agriculture with the aid of advance technology is very essential and significant in developing countries. Therefore agriculture 4.0 is progressive and advance in nature and it has potentialities to extend the growth of economic[26],[29],[39].

Agriculture 4.0 and India

India is the agricultural country. Agriculture is the base of India. Agriculture in India has many contributions in economic development. Agriculture sector profit 17.8% country's Gross Value Added (GVA) in India[10],[18],[19]. India export $50.2 billion agriculture products during the year 2021-2022. Therefore, India is growing in agricultural sector. Agriculture 4.0 is expanding in India due its demand and probable future opportunities. The agriculture in India provides employment opportunities, food safety, reduce poverty, and build up strong economy. To overcome the several environmental barriers in agriculture including flooding, drought, natural disaster innovative technologies imposed in agriculture in India. Agriculture 4.0 is implemented in Indian agriculture to improve the productivity by overcome the challenges of environmental impact on agriculture[13],[14],[31]. There are huge prospects in development of agriculture in India. Agriculture 4.0 is the innovative invention of digital technology based agriculture system. Therefore, application of agriculture 4.0 is highly essential for the agricultural country India. Some application of technology based agriculture 4.0 in India are Drone technology in agriculture, Agriculture imaging system, vertical farming, and diversification in agriculture system[15],[17],[42]. As per the government initiative digital technology based agriculture developed in India. Agri-tech business is the innovative technology based application to extend the productivity. Government take initiatives to established agriculture 4.0 in India. Different application and system build up to extend agriculture in India including farm safety app, mobile app that implement for roof water harvesting[16],[33].

CONCLUSION

Modern and advanced agricultural systems are truly associating with various technologies and tools viz. Database Systems, Networking Technologies, Web Systems and Management, Multimedia Systems, and as far as latest technologies are concerned artificial intelligence, machine learning and deep learning, robots, big data and analytics, cloud computing, augmented reality, etc. are considered as valuable and impactful *in order to build precision agriculture more effective profitable, efficient, safe, and environmentally friendly. In addition to mentioned technologies* Internet of Things (IoT) are dedicated in enabling precise field management supported by 5G networks in order to deliver high quality farming videos, seamlessly connected devices using 5G can be more productive and effective. Swarm intelligence, AI algorithms, Cloud and Blockchain based systems no doubt important and impactful in planning of farming equipment. All these latest technologies and systems are dedicated and responsible in building an advanced agricultural systems effectively for future food security concern.

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