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The Agriculture Revolution 4.0: A Journey towards Sustainable Farming

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Agriculture is considered a key sector providing food for the growing population and ensuring the viability and resilience of rural areas. At the same time, agriculture is facing a number of global challenges related to the scarcity of resources, climate change and food security. A new possibility to overcome these global issues, Agriculture 4.0 comes into the same. Agriculture 4.0 as a term is related to different concepts such as digital agriculture, smart agriculture, vertical farming, and precision farming. In addition, it is expected that Agriculture 4.0 will impact the production systems and agricultural supply value chain. Along with the number of benefits related to increased productivity and environmental protection some outline challenges are associated with the social effect of digitalization. (Uzunova *et al* 2022)

Concept of Agriculture 4.0

Agriculture 4.0 is known as the fourth agricultural revolution. The main focus of Agriculture 4.0 aims to increase technology adoption rates in farming, driving effective and efficient change that increases productivity in a sustainable and eco-friendly way. Agriculture 4.0 focuses on using robotics and artificial intelligence (AI), Internet of Things (IoT), Vertical farms, drones in farming practices. This adoption ultimately leads to increased crop yields, cost and manual labor reductions, along with reducing the wastage of water, pesticides and fertilizer.

Agriculture Evolution: Concept and Evolution

Agriculture 1.0 added the steam engine as the steam tractor. Agriculture 1.0 is subsistence farming that uses traditional farming practices. Electricity gave way to Agriculture 2.0, which provided industrialization solutions that helped increase production capacities, mainly in the post-harvest process, such as oil mills. Agriculture 2.0 has a mandate to feed 9 billion by 2050. The 20th century introduced Agriculture 3.0 where it was possible to automate agricultural processes, making it normal to see machines that carry out the complete cycle in tasks such as planting, harvesting, fertilization, etc. Now with the fourth agriculture revolution popularly called Agriculture 4.0. Agricultural world has begun to notice improvements e.g. through exploitation of information. Information is being interconnected and being used , for example, meteorological information, monitoring of pests and diseases, in order to achieve better planning of the use of water, fertilizers and phytosanitary products . For this, it is necessary to install sensors on the land and to have the capacity to process the data as well as to ensure their transmission. (de Mexico 2022)

Agriculture witnessed four phases of transformation

It stated that agriculture 1.0 is labor intensive and related to animal force use (Zhai *et al* 2020). Agriculture 2.0 is associated with different agricultural types of machinery. Various

chemicals are also introduced. However, these trends increased productivity but also caused environmental harm and waste of resources. Computer technologies led to the development of Agriculture 3.0 in the 20th century. The application of chemicals was reduced. The sustainable agricultural development concept was introduced (Rapela 2018). However, the global challenges the world faces alongside the rapid development of digital technologies emerged in Agriculture 4.0 (Ferrandez-Pastor *et al* 2016).

Agriculture 4.0 New Technologies Involved:

Agriculture 4.0 need to look at both the demand side and the value chain/supply side of the food-scarcity equation, using technology not simply for the sake of innovation but to improve and address the real needs of consumers and reengineer the value chain. Three general trends where technology is disrupting the industry that we will address, showing specific examples of solutions with high potential to disrupt the system:

1. Produce differently using new techniques
2. Use new technologies to bring food production to consumers, increasing efficiencies in the food chain
3. In-corporate cross-industry technologies and applications (Clercq *et al* 2018)

Technologies in Agriculture 4.0

1. **GIS (Geographic Information Systems) technology:** GIS software works on a location basis, so it has the imminent use in the accuracy of farming of crops. With this software, a modern farmer can plan a map of current and in future changes in climate like change in temperature, formation of precipitation and crop production, crops health and many more.

Application of GIS in Agriculture

- Agricultural Mapping
- Management of agricultural production
- Efficient farming technique
- Determine land use/land cover changes

2. **Artificial intelligence (AI) technology:** Artificial Intelligence has become one of the most important technologies in every sector, including education, banking, robotics, agriculture, etc. In the agriculture sector, it is playing a very crucial role, and it is transforming the agriculture industry. AI saves the agriculture sector from different factors such as climate change, population growth, employment issues in this field, and food safety. Today's agriculture system has reached at a different level due to AI. Artificial Intelligence has improved crop production and real-time monitoring, harvesting, processing and marketing. Different hi-tech computer-based systems are designed to determine various important parameters such as weed detection, yield detection, crop quality, and many more. The major AI applications in making agriculture a smart field fall in three categories, including:
    - Agriculture Robots (Agbots)
    - Drones, Satellites and Planes
    - Smartphone Apps
3. **Weather Tracking Technology:** This technology is available even in your smartphone. There are various online weather services that focus on agriculture related information, and the farmers can easily access these services on dedicated onboard and handheld farm technology even via their mobile phone apps. This technology gives farmers enough advanced notice about the upcoming frost, rain, hail and other weather, on the basis of which farmers can take precautions to protect the crops or at least mitigate losses to a significant degree. (Dhiman 2020)
4. **Vertical Farming Technology:** It is a component of urban agriculture that is the practice of producing food in vertically stacked layers. Perhaps the most obvious is the ability to

grow within urban environments and thus have fresher foods available faster and at lower costs. However, vertical farming won't be limited to just urban environments like initially expected. Farmers in all areas can use it to make better use of available land and to grow crops that wouldn't normally be viable in those locations. Vertical Farming is the method of producing food on vertically stacked layers. It aids in maximizing production output in a limited space. These systems are built-in facilities such as a skyscraper, tunnels, shipping containers, old mine shafts, or repurposed warehouse. These facilities function through Controlled Environment Agriculture (CEA) techniques (hydroponics, aeroponics, aquaculture, and aquaponics) to artificially control temperature, light, humidity, pests, and gases. Vertical farming examples: AeroFarms, IKEA's Malmö store

5. **Hydroponics:** Hydroponics, a subset of hydroculture, is the method of growing plants without soil, using mineral nutrient solutions in a water solvent. Sundrop, for example, a company based in Australia, has developed a hydroponics seawater technology that combines solar, desalination, and agriculture to grow vegetables in any region. This system is sustainable, doesn't rely on fossil fuels (drawing its energy from the sun instead), and doesn't require land. Instead, its technologies integrate solar power, electricity generation, freshwater production, and hydroponics.
6. **Cattle tracking:** A system that uses IoT sensors, cloud, and GPS-enabled devices, to help ranchers can track cattle over a large area. Its benefits include: Precise animal identification, Heat detection to improve conception and insemination, Disease tracking, Track head patterns, Mastitis detection, Manage rations, Animal stress levels, 24×7 monitoring, Long-range, Prevent animal theft, Reduce manual labor, Waterproof and weatherproof technology, Cheap implementation cost, Inactivity detection, Easy connectivity to cloud, help make informed decisions.
7. **Sustainable Packaging: Bioplastics:** New technologies and solutions are disrupting not only the production side of the value chain but also food packaging. And it's long overdue, what with 100 million tons of debris drifting in the oceans, much of it disposable plastic- food packaging containers and bags. Consumers increasingly are urging companies to develop food containers that can be recycled and are biodegradable or compostable too. Bioplastics have been around for more than 20 years. However, they haven't managed to deliver on the promise of bringing the same packaging usefulness as plastic and returning 100 percent back to nature, with no harmful impact.
8. **Urban Farming:** Urban agriculture can be practiced either in an intra-urban (within the city) or peri-urban area. It can be done on your own plot where you stay or on another plot beside your homestead. You can also do it on a leased piece of land or with the right permissions on public land such as parks, conservation areas, along railways, streams, and roads. Some people even practice this type of city agriculture on schoolyards and hospitals. Just make sure you have the right permissions to use the land for agricultural purposes. Unlike regular farming done on tracts of land, an urban farm can be created on a balcony, backyard, and even on a flat rooftop. It is also practiced on vacant plots within the urban setting.
9. **Smart Cameras:** It is used to monitor crops and obtain information. There are different types such as conventional cameras or Hyper spectral, with which the composition of crops can be analyzed and data that is not visible with the human eye can be obtained. (Dhiman 2021)
10. **Remote Sensing:** IoT based remote sensing utilizes sensors placed along the farms like weather stations for gathering data which is transmitted to analytical tool for analysis. Detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from a satellite or aircraft). Farmers can monitor the crops from analytical dashboard and take action based on insights.

Strategies for promotion Agriculture 4.0 by extension agents:

Greater participation of farmers particularly small and marginal farmers in agriculture 4.0 may be encouraged keeping in view the opportunities for improving farm income. The core strategy involves adopting a compact area and activity specific development approach to enable input, technology and extension support, creation of critical common infrastructure and aggregation of production for marketing and value addition. Some of the suggested strategies include:

i. Study of successful models for replication (i.e. Precision farming programme in Tamil Nadu)
ii. identifying activity/crop specific locations and potential mapping
iii. Development with Group approach such as Farmers' Societies, Producer Companies, JLGs /SHGs, etc.
iv. Assessment of infrastructure needs including post-harvest handling and transport logistics
v. Preparation of Sector/ activity specific credit linked Development Plans (Area Development Plans / Banking Plans)
vi. Supporting infrastructure for post-harvest handling, warehousing, marketing, etc. through PPP mode or private sector investments.
vii. ICT and AI enabled services such as market information, technology inputs and credit access

Extension approaches for resource poor farmers:

i Group approach: FPOs, NGOs, FIGs, progressive and large farmers
ii Co-operative society
iii Private companies
iv Government initiatives

Barriers to Adoption of Agriculture 4.0

The development of agriculture 4.0 often does not reach its full potential because of the complexity of the agricultural ecosystem which is in the transformation phase. In addition, external factors such as the influence of climate and environment also make it more difficult to advance this process. Due to the diversity of agriculture in the world, there are barriers that must be resolved in different areas to achieve broad adoption of agriculture 4.0. The barriers as the most prominent in the agricultural production chain: concern with issues of data reliability (cyber security), lack of infrastructure (lack of robust connectivity in the rural area), lack of usability of technological equipment (technological complexity), lack of digital skills or skilled labor.

Although Agriculture 4.0 is a widely discussed topic and the benefits of its implementation are identified in scientific literature, there are a number of challenges for developing the new concept. Based on the literature review, da Silveira *et al* 2021 divided the main barriers of Agriculture 4.0 implementation into five dimensions: technological, economic, political, social, and environmental.

1. As technological barriers can be considered operational and technical problems. Other issues are associated with managing information and data. The implementation of Agriculture 4.0 requires the development of infrastructure in rural areas, and the lack of it is seen as a significant challenge (Brunori *et al* 2019).
2. The main economic barriers are linked to the high investment costs. The social and environmental implications may also lead to potential costs that are challenging agriculture 4.0 implementation and diffusion.
3. Political barriers include differences in the politics created by developed and developing countries (Ferrandez-Pator *et al* 2016).

4. Environmental barriers are linked to the capability of Agriculture 4.0 technologies to influence the climate and the behaviour of the system. The limited acceptance of agricultural technologies are also a challenge.
5. One of the main barriers to Agricultural 4.0 implementation is the infrastructure and digital skills.

Conclusion

It is concluded that agriculture 4.0 is future of farming technology. Currently ICT is established right now but agriculture 4.0 are the future of the farming. These technologies include IoT, AI, Expert system, GPS etc. Agricultural applications using Agriculture 4.0 found to increase operational efficiency, lower costs, reduce waste and improve the quality of yield. It will prove to be instrumental in enhancing efficiency, improving quality and lowering costs. Drones and robots are more specialized technology capable of assisting farmers in wide range of operations. Ever rising global population is pushing agriculture towards modernization and intensification. Extension should be focused on disseminating these modern technologies. Though, it has lot of potential and benefit but agriculture 4.0 has a lot of barrier to overcome like technological, economical, political, social etc. Government intervention, promotion by extension agencies, creating awareness and handholding of farmers is utmost requirement for popularizing these technologies.

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