AI-BASED SMART AGRICULTURE FOR SUSTAINABLE GROWTH - THE LINKAGE BETWEEN AI, IOT, SUSTAINABLE GROWTH AND DEVELOPMENT – AN INDIAN PERSPECTIVE

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Abstract :

The growth and development of agriculture in the economy in the future will depend greatly on the use of appropriate technologies. We need to understand and examine AI and IoT applications, which integrate to provide the solution to the agriculturist and can aid greatly in effectiveness, productivity, resource allocation, and output enhancement, using multi-cropping, and mixing & match of the crops depending on weather and soil conditions. AI has helped modern industry and economics greatly. AI shapes the circular economy and how we collaborate across industries, in organizations, and in everyday life. AI in agriculture relies largely on technology and the circular economy idea. AI in agriculture will assist develop new tools, goods, and applications and add value to outlays. Increasingly, the Circular Economy and agricultural innovations are combined to promote sustainable growth. Again, AI helps us address these difficulties. The breadth of AI applications in agriculture in a circular economy is vital to continuing our growth and assuring its sustainability in the future. The present pandemic-induced behaviour has emphasized the need to move the value chain of products and services into the digital mode, integrating platforms, GUIs, and technologies with Open source applications. AI is likely to play a crucial part in this process. The authors analyzed the available literature and provide their opinions on what AI's function may be in the agriculture sector of the economy to make economic development more sustainable and helpful while boosting the farmer's standard of living and ability to integrate advantages. AI technology and disruptive breakthroughs are anticipated to arise in our Indian economy and will work as a growth accelerator, integrating IoT-controlled devices to improve farm productivity. The authors proposed a theoretical framework model.

Keywords : *Artificial Intelligence, Sustainable growth, Agriculture, Circular Economy, IoT Devices, Economic Development, Opensource Integration, Agro Startups, Smart Agriculture, Smart Farming, Environment, and Agro-Business Models.*

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1. INTRODUCTION

The Role of the Circular economy in today's economic development, with the advent of Artificial Intelligence (AI) in recent times, has gone through a radical transformation, especially in the type of technologies, the applications and the sectors they are found to be a part of. As we move into the future, the Circular Economy (CE) is going to face the impact of AI in both its variants – the benefits as well as the unmitigated ills which come along with the technology. It is therefore imperative for us as the users and developers of technology, the products, and the application to how ready we are to face the challenge. While our inability to face the challenges will only be a setback to our efforts albeit temporarily, the positive side reflects an upside from an SDG perspective. CE with AI pervades all areas from the water supply, energy management, waste management, efficiency improvement, effectiveness and value chain migration and general industrial output growth by a high factor. The new sectors where AI is likely to play in CE roles are related to country-wise classrooms, low-cost distributed education systems, health care, logistics, food chain, space and defence, and construction of smart cities, waste management. CE with AI can be a potent recipe for accelerated growth in the post-pandemic, capital-starved phase for a large nation like ours and enable better value addition and outputs of goods and services, without taking heavy debt. It is here Technologists, sociologists, Government and entrepreneurs alike are finding it difficult to cope with a shorter shelf life for technologies, tools, platforms, interfaces etc. which are getting continuously upgraded or replaced by new ones. The regenerative nature of a circular economy will enhance our ability to cope with the capital-starved sectors and is likely to accelerate innovations soon.

The recent pandemic had its implications in terms of affecting the business climate, the economic growth, credit available to the industrial units, consumption by households and imposed a higher burden of health care costs on society. These in turn all the more make it imperative for us to focus on the effective use and adoption of AI technologies in CE for the development of the various sectors and improve the effectiveness of the use of resources at our disposal in a measured and fair manner in the future.

The author here proposes to examine past literature in this regard and the way the society and economy are going to be shaped by the increasing role played by AI in today's circular economy in day-to-day life, and its effect on sustainable growth. The likely impact of the same in the future, as well as the sectors that are likely to be affected, are also outlined in brief.

2. OBJECTIVES OF THE STUDY

a) To examine the role played by AI in the agriculture sector.

b) To study the close linkages which exist between sustainability and circular economy, and the increased application of smart devices in agriculture applications.

c) To suggest measures that can assist and improve the effective increase in output given the constraints in land area and water bodies.

3. REVIEW OF LITERATURE

AI and Internet of Things (IoT) technologies in use today in the circular economy are so extensive that it has become a catalyst for growth and economic development can perhaps be done effectively only by recourse to the use of technologies, and increasing applications of these are likely to be found in agriculture using smart technologies which has extensive applications wide ramifications in the agriculture sector and the general economic conditions, for societal growth. AI has thus become more focused, and the technologist has to closely work with development economists and sociologists for making it better for use and application to different tasks required by society. AI thus enables growth, and sustainably cost-effectively using affordable technologies, with long-term sustainability in view. An integrated approach to projects and executables is called for considering the rapid pace at which AI is coming into our lives on a day-to-day basis. The author believes that certain sectors in circular economy like water, energy consumption, food chain, logistics, environmental resource protection, and effective waste management will heavily be utilising AI applications for solutions- and these will give the maximum payoff.

Ciruela-Lorenzo, A. M., Del-Aguila-Obra, et al (2020), mention that one of the main problems for organisations in the twenty-first century has been the utilisation of digital technologies. The intensive application of information technologies at various stages of a sector's value chain characterises this digitalization. Smart agriculture is revolutionising agriculture in terms of economic, social and environmental sustainability, in this context. Cooperatives, as the most prevalent legal form of incumbent enterprises in this very conventional low-intensive technology sector, will play an important role in the adoption of these technologies in various nations. This paper first presents an overview of the emergence of key digital technologies such as the Internet of things, AI, Big Data, and Blockchain, among others. Secondly, a description of the digital innovation process in Agri-coops to aid decision-making, and thirdly, a digital diagnosis tool to assess cooperatives' digital innovation. This method is first used in two Agri-cooperative cases in Spain. All of this helps to help improve understanding of Agri-cooperative digitization in the context of smart agriculture.

Chukkapalli, S. S. L., Mittal, S., Gupta, M, et al (2020), mention large volumes of data are generated by Cyber-Physical Systems (CPS) and the Internet of Things (IoT), resulting in the emergence of AI-based smart applications. Agriculture and farming are changing to an IoT-connected ecosystem to balance the growth in demand for food supply, driven by rapid improvements in technologies that support smart devices. It is now conceivable to add AI-assisted systems at a cooperative (co-op) farming level when the number of smart farms reaches critical mass. There are currently about 1,900 co-ops serving 189 mill farmers in the United States alone. As a result, incorporating new technology and infrastructure into the co-op farming ecosystem can greatly benefit small member farmers who operate and maintain these self-contained co-ops. They create a connected co-op ecosystem in this work that deals with sensors and their communication with diverse entities, as well as a cloud-based co-op hub. To capture data and numerous interactions that happen between shared resources, member farms, and the co-op that are saved in the cloud, they constructed member farms and co-op ontologies. These can then be used to help farmers and the co-op create AI-based insights. Using case scenarios the co-op farming systems were explored, discussed several AI applications that can be used by co-op members to assist them.

Alves, R. G., Souza, G., Maia, et al (2019), mention that using the technologies created by the Sensing Change and Smart Water Management Platform projects, this study offers a digital twin in the agriculture area. The project is now building an Internet of Things platform for farm water management, while the Sensing Change project produced a soil probe. This study takes advantage of the technologies established by those programmes by creating an initial digital environment to create a Cyber-Physical System (CPS) that allows farmers to better understand the state of their farms in terms of resource and equipment consumption. They conclude that their system can collect data from the soil probe and show it in a dashboard, allowing for the deployment of additional soil probes and control devices to create a fully functional digital twin.

Goel, R. K., Yadav, C. S, et al (2021), Science, innovation, and space technology are the three main pillars for smart agriculture. These are the three foundational pillars of nation-building. Space technologies are critical for increasing soil quality, minimising irrigation waste, and exchanging agricultural information with farmers. A significant number of geospatial data from many sources is collected, evaluated, and used for smart farming and crop shielding with the help of terrestrial, aquatic, and aerial sensors, satellites, and surveillance equipment. Drones in agriculture, precision gene processing in plants, epigenetics, big data, and the internet of things (IoT), utilising all sources of energy efficiently, such as smart wind, solar energy and robots based on artificial intelligence are covered in the technology foresight. Some of these breakthroughs are already in use in industrialised countries. The adoption of digital farming in rural areas would be a benefit for the agriculture industry, which plays an essential role in emerging economies. By 2030, emerging countries will account for 85 per cent of the global population. In this scenario, developing countries urgently require data-driven technology growth to boost GDP and ensure food security for their populations.

Hassan, S. I., Alam, M. M., Illahi et al (2021), Agriculture automation is currently a major priority and area of development for several countries. The world's population is fast expanding and will double in the coming decades, necessitating an increase in food demand. Agriculture automation is the best solution for meeting this significant increase in demand. Farmers' traditional techniques are not effective enough to meet the expanding demand. Agricultural growth is disrupted by improper use of nutrients, water, fertilisers, and pesticides, and the land remains barren and devoid of fertility. They discuss- IoT, aerial photography, multispectral, hyperspectral, NIR, thermal camera, RGB camera, machine learning, and artificial intelligence techniques as well as other control tactics used to automate agriculture. Plant diseases, pesticide control, weed management, irrigation, and water management are all problems in agriculture which can be readily solved with the various automated and control approaches stated above. Automation of agricultural operations using advanced control tactics has proven to boost crop yield while also strengthening soil fertility. This research paper examines and evaluates the work of various researchers to provide a quick overview of smart agricultural trends, as well as the workflow and revenue of smart agriculture systems based on technologies validated by researchers in their research papers.

Friha, O., Ferrag, M. A., Shu, L., et al (2021) article provides a comprehensive overview of developing technologies for smart agriculture based on the IoT. They start by reviewing existing surveys and describing emerging agricultural IoT technologies like unmanned aerial vehicles, wireless technologies, open-source IoT platforms, software-defined networking (SDN), network function virtualization (NFV) technologies, cloud/fog computing and middleware platforms. They also divide IoT applications for smart agriculture into seven groups: smart monitoring, smart water management, agrochemicals applications, disease control, smart harvesting, supply chain management, and smart agricultural practices and present a taxonomy and a side-by-side comparison of state-of-the-art methods for agricultural IoT supply chain management based on blockchain technology. Furthermore, it provides real-world projects that demonstrate the superior performance of the aforementioned technologies in the field of smart agriculture. Finally, it explores potential research paths for agricultural IoTs while highlighting open research difficulties.

Islam, N., Rashid, M. M., Pasandideh, et al (2021) mention smart farming is utilising the Unmanned Aerial Vehicles (UAVs) and Internet of Things (IoT) paradigm to achieve the goal of sustainable agriculture. Interconnected gadgets and vehicles are used to run these smart farms. Integration of several IoT technologies can be used to produce automated activities with minimal oversight, which has huge potential. This article examines the communication technologies, network functionality, and connectivity needs for smart farming, as well as some of the primary uses of IoT and UAVs in smart farming. Two case studies are used to examine the connectivity limits of smart agriculture and its remedies. To solve the connectivity restrictions of Smart Farming, they propose and evaluate meshed Long Range Wide Area Network (LoRaWAN) gateways in Case Study 1. In case study 2, they look into using satellite communication systems to connect smart farms in remote areas of Australia., and also highlight future research problems on this topic and suggest potential solutions.

Various studies that have been conducted in the past have already established the importance, relevance and linkage between IoT, Smart agriculture, AI in Circular economy, AI in agriculture, integration technologies which play a key role in the agriculture sector and sustainable growth therein and studies have impressed on adopting new technologies which are more effective by the use of AI towards sustainable growth, in a circular economy.

4. DISCUSSION:

The authors after having reviewed the above literature review, the current economic and global conditions, believe that given the current dimensions of problems in the world we are in, it is essential for us to accept that Agriculture, CE, AI, Smart devices and utilities are getting closely linked and the linkage to sustainable economic growth, is growing and if applied properly can be of good help to emerging economies and countries to take the agricultural sector and output in the country on the path of growth and development, albeit in a sustainable manner. Use of space technologies, remote sensing and usage of big data, images from satellites appear to be playing a crucial role in this regard. And help integrate the different elements in the agricultural sector, leading to holistic development – can be adopted as a nationwide movement and can be most useful in the sustenance of the economy.

- The importance of Smart farming, AI and circular economy can be better understood particularly in the context of global warming, increasing frequency of losses due to natural calamities and the need to feed a huge growing population globally.
- Proper application of AI in agriculture and thereby in the CE, will lead to a sustainable business model, that will help enhance output, facilitate more recyclable products, improve energy efficiencies and enable better allocation of resources across sectors. It will also help in identifying ways and means in which innovation can happen and help industries in recycling waste using new and emerging technologies.
- The use of Smart technologies will help agriculture in improving productivity and effectiveness. AI in agriculture will help the smaller towns and villages depending primarily on agriculture to be more agile and self-reliant, support the Atmanirbhar Bharat initiative and increase the proficiency level of farmers to take sufficiently good precautionary measures to counteract natural calamities, minimise losses, avoid infection of the crop by pests, build more resilience into their eco-systems and increase their ability to develop more value for an amount spent, e.g. developing better yield crops for a given outlay multi-cropping patterns, crops that can adjust to climate changes happening and thus can enable service societies and communities on lower budgetary allocations.
- Factors affecting the output – rainfall, temperature, pressure, height, soil conditions, cropping pattern, pest effects, fertiliser effects, and duplicate seeds, can be identified using suitable AI and IOT algorithms that can be enabled by technologists working in conjunction with agricultural scientists.
- An institutional framework for creating an open source database for identifying correct seeds for farmers - removing the middlemen effect and pricing to be normalised using a supply-demand mechanism with government intervention can also be thought of.
- Rent for drone technologies or purchase – financing arrangement for the procurement of drones, power weeder and other agricultural inputs using soft loans and subsidies, should be given a preference for marginal farmers and issued on need-based requirements.
- Cost of dripping technology – to be reduced by suitable material substitution, and design changes, so that the effectiveness of the irrigation system is improved and the water management program upgraded suitably. Part subsidisation for power supply – by alternative measures like Solar, wind energy be thought of.
- Pesticides – their effects, vs the diseases they are related to and identification or matching of pesticides to specific diseases. A simple method of understanding the same, and an integrated database containing the same – available on a low-priced subscription model for farmers and eco-system be set up.

- ➢ Digitalising of all data related to farm location, soil conditions, water bodies and effective waste management processes to be integrated into the mainstream system so that farmers can access the same at low cost.
- ➢ Crop database and other inputs need to be suitably integrated at the district level and taluk level so that the same can be integrated with other IoT devices and platforms to enable collect information data and feedback at the state level and country level. This would necessarily call for massive integration efforts, design and deployment of new technologies for interfaces, investment of sizable orders and a well-programmed project management set-up.
- ➢ The Govt should set up a suitable framework for this purpose and see that the issues if any are thrashed out and deliverables are capable of being met in a time-bound manner.
- ➢ Agriculture and Circular economy, being interrelated, AI applications therein can bring revolutionary changes in approaches to issues confronting the farmer.
- ➢ Special training and classroom assistance using the E-learning mode of Television broadcasts and Radio (as earlier) can perhaps be more interactive and help understand the farmer's problems so that the technologist can design appropriate solutions.
- ➢ Agro–start-ups, Technology disruptors and Business incubators can come together with environmental experts to resolve the issues facing current global problems afflicting agriculture. In this regard, the role of Govt is important to provide for an institutional framework that is sustainable and supportive. Thus regenerative and recyclable technologies in Agri-tech need to be suitably encouraged by funding and incentivise from a system perspective. These actions can have the potential to change the practices and in turn, the output, effectiveness and efficiency level of smaller towns and villages as well as the rural landscapes to a great extent.
- ➢ AI-enabled agriculture integrated with IoT and linked to a CE is capable of making the environment more sustainable and this reduces strain on resources both in the various business models involving industry and agriculture sectors and can adopt regenerative technologies.
- ➢ Environmental problems can better be dealt with by recourse to regenerative and reusable technologies and will thus contribute to lower pollution of air, soil and water. This improves indirectly the yield from agriculture and can step up growth, and transform future practices in Agriculture to be aligned to SDG in long run.

5. PROPOSED THEORY FRAMEWORK – A POSSIBLE STRUCTURE

After reviewing previous studies, the authors attempted to develop a possible theoretical framework that could assist entities, farmers, and policymakers in taking appropriate action and developing guidelines that could help to accelerate the adoption of AI and smart farming in agriculture. The variables have been categorised into two factors – IV (independent variables) and DV (dependent variables).

Dependent variable:

Y = Crop output (quality and quantity, substitutability of crops)

Independent variables: X_1 = Water resources availability, X_2 = Rainfall, X_3 = Air pollution in local areas, X_4 = area under irrigation, X_5 = climate change, X_6 = altitude, X_7 = temperature, X_8 = soil condition, X_9 = Soil erosion, X_{10} = use of organic / non-organic farming, X_{11} = cropping pattern adopted, X_{12} = crop type, X_{13} = Smart agriculture practices, X_{14} = global warming effect, X_{15} = IOT technologies adopted, X_{16} = Investment in smart farming techniques, X_{17} = Govt subsidy for IOT devices

$$\boldsymbol{Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{11} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17}}$$

Solving the above for the system of equations, we are in a position to obtain the required values for the variables as output, being the result of crop yield, output and quality, and substitutability. The above is a simple version of a theoretical model or framework—which needs to be modified suitably and manipulated to arrive at a final value of crop yield and quality. The authors also feel that linear systems of equations may be simpler to handle in the above case as compared to non-linear systems. For the functions and operations to be done, a set of partial differential equations will be used. As the authors observe from past studies, decision tree applications using ML and interaction regression models can be used. Additionally, with AI-based deep learning models using neural networks becoming more popular, it is expected that these areas can also be well covered and solutions obtained in the process. The government could set up the necessary infrastructure and framework and use research labs like CSIR, ICAR, and NIAR to start these activities.

6. LIMITATIONS OF STUDY

The study is exploratory and does not consider the limitations imposed on agriculture-related technology transfers, disparities in political systems and other factors which limit the free flow or diffusion of technologies. No empirical validation has been discussed.

7. CONCLUSION

The Importance of AI in CE and its contribution and its role in Sustainable Economic growth is very vital indeed and it is a fact that we can ill afford to ignore. Effective waste management in all forms is a precursor to ecologically sustainable growth as the global problems mount in all directions like global warming, population growth, resource constraints, meeting sustainable development goals, and income disparities widen across different economies and sectors, it becomes all the more necessary to have a better handle on how we use AI in CE, for our benefit as between the various stakeholders and develop and nurture an eco-system that makes it mandatory. It also allows for additional incentives for players in the CE for adopting AI technologies that can be directly linked to a sustainable and eco-friendly economy in the long run. The linkage of AI to CE and its impact is visible to us in the development of many products that can help members of society to meet their aspirations albeit at a lower level of resource utilisation in the CE and reduce the usage of material, energy and resources, ultimately resulting in an affordable cost in long run.

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