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AI And IOT In Smart Agriculture: Enhancing Productivity, Sustainability, And Resource Optimization

[1]Pitta Chandra Shekhar Reddy, [2]Dr. Dr.Rajeev Dahiya
Research Scholar, Desh Bhagat University, Mandi Gobindgarh, Panjab
Professor, Desh Bhagat University, Mandi Gobindgarh, Panjab

ABSTRACT
The integration of AI and IoT (AIoT) is useful to solve some of the challenges that currently affect agriculture such as food insecurity, climate change and scarcity of resources. The utility of AIoT in smart farming through IoT-enforced sensors, drone surveillance, and an analytics platform is also elucidated by detailing the application effective irrigation, sound animal husbandry, and efficient greenhouse climate control which go a long way in cutting on wastage and optimizing production. Nonetheless, several factors such as; cost issues, which imply that affording access to the internet is economically costly, connectivity issues, particularly in rural areas and issues to do with data privacy act as barriers to adoption. The suggestions given involve putting more effort into policy interventions, educating farmers, and availing cheap AIoT technologies for closure. Automated labor, blockchain-based food tracking, and climate change forecasting are here some of the examples of application of AIoT for positive development of resilient, inclusive and sustainable food systems.
Keywords: *AIoT, climate-smart agriculture, precision agriculture, food security, digital divide, sustainable farming, IoT sensors, drone technology, data privacy, farmer adoption, blockchain, predictive modeling.*

I. INTRODUCTION

With more than 9 billion people predicted to be the global population by 2050, the use of advanced technologies in agriculture is inevitable to tap into food demands. The combination of AI and IoT also has revolutionary characteristics that have the potential to revolutionise farming, resources, and climate. Nonetheless, the positive impacts of AIoT are not reciprocal since most of the smallholder farmers and dwellers in the rural areas cannot afford the costs, lack digital skills, and lack adequate infrastructure. This paper examines the socio-economic aspect of AIoT with a focus on taking up precision agriculture, livestock farming, and food trackability; equally, the focus is on the issue of ethical considerations, equity, and policy implications. Using success stories and implementation barriers, this research supports inclusive policies and approaches and accessible technologies as well as capacity-building to increase overall stakeholder enabling and productive usage of AIoT. The insights provided in the article can be beneficial to policymakers, agritech firms, and farmers in the creation of a more sustainable and remedial agricultural sector.

II. LITERATURE SURVEY

Thus, adopting AIoT technologies has potential for the agriculture industry and its productivity and efficacy; however, there are social and economic challenges that still hinder its application depending on the type of farming and geographical location. There are trends on these challenges noted in the literature and the possibility of solving them as well.

Consequently, another major consideration is the economic viability by which profit motive is a dominant consideration, especially for smallholder farmers. [18] & [19] reveal that the cost of basic AIoT systems varies from $5000 in the initial stage, which is unachievable by most of the SMEs. Some researchers on the use of technologies in developing countries have established that although technologies may be subsidised, the cost of maintenance and technical support always constitutes subsequent hurdles [20]. Nevertheless, several real-life examples provided in [21] show that co-ownership arrangements ensure that these technologies are available to farmer associations.

The last but not the least significant challenge is the divide in the rural region on the use of advanced technology. A study by [22] shows how a lack of internet connectivity and electricity, most often an issue in the agricultural areas, prevents IoT implementation. There are currently some innovative approaches, like the use of solar-powered LoRaWAN networks proposed by [23], but the coverage is still a major concern. Farmer digital literacy is also not relative since [24] discovered that only 28% of farmers within the developing countries in the study were confident in smartphone-based agricultural applications.

The essential thing that one should understand is that culture and behaviour are very crucial regarding technology acceptance. The study conducted by [25] points out that trust is an essential component, and farmers are willing to adopt systems that are opted for by their fellows rather than those presented by outsiders. Gender inequalities are also present, which was seen from research by [26] on the fact that women farmers are limited in their access to technology and adequate skills. In line with this, alternatives of participatory design have been shown to improve the usability of the interfaces and capacity of the locals, as noted by [27].

This paper found that policies and institutions support the diffusion of technology to be equitable. Literature from [28] presents how national strategies on the use of digital agriculture in the likes of Kenya and India have institutions through incentives as well as capacity building. Nonetheless, [29] cautions against the top management's enforcement of plans that may fail to capture the context of regional environments by supporting decentralized management structures.

As the purpose of this paper, ethical consideration seems to be receiving more attention in recent years. The issue of data ownership in precision agriculture is covered in the research by [30] and the focus on privacy within farms with the use of surveillance technologies is featured in [31]. This is in agreements with the findings of [32] who argues that there will be a need to come up with ethical standards and legislation in order to support these systems.

Taking into consideration of several useful tools for increase percentage of high quality mobile learning and representative successful case studies is the following: [33] providing a case on the use of locally developed AIoT systems integrated with the farmer field school model to promote the adoption of AIoT. As [34] points out elsewhere, successful public-private partnerships in Vietnam have influenced information and communication technology adoption by small scale rice farmers. Such approaches indicate that when adoption processes are approached from an implementation-context perspective – actively involving intended adopters – and reinforced by policies that are supportive of the process, most of the barriers are easy to overcome.

III. PROPOSED SYSTEM

A system condition to the adoption of modern agricultural technologies is;

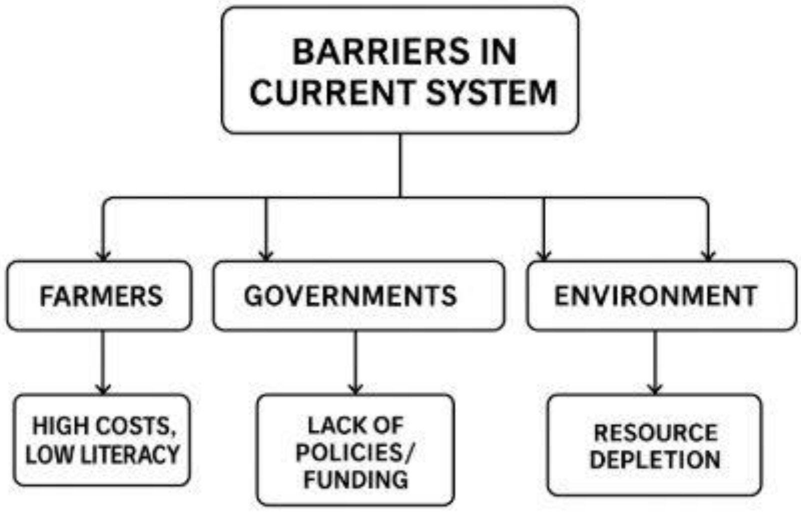

Fig 1: Barriers in Current System

Economic Limitation: Small farmers can hardly adopt the IoT/AI tools because they are expensive such as a chipset which costs $5,000 [8].Open Issues: Some of the challenges faced by rural areas include: [9] There is the availability of a stable connection reliable internet connection/ power source for IoT devices. Knowledge Gaps: Limited technical training leaves farmers skeptical of AI solutions [10].Policy Gaps: Absence of subsidies or regulations for smart farming [11].

Impact:

Digital Divide: Seven out of ten smallholders are deficient to precision tools [12].

Yield Losses: Lower yield by up to 30% to what is obtained in AIoT-environmented farms [13].

IV. OBJECTIVES

Socio-Economic Objectives

- **Adoption Barriers**
  - ✓ Assess the feasibility of the implementation of AIoT at small holding of farms that are below 5 acres in size [12].
  - ✓ Assess what roles, tasks and information elements are most important to farmers in order to judge their readiness for AI interfaces [13]
- **Policy & Infrastructure**
  - ✓ Suggest the policies or variations for the promotion of AIoT in developing countries [14]
  - ✓ Identify the barriers that exist in the rural areas that hinder IoT deployment – cellular and/or LoRaWAN [15]
- **Equity & Ethics**
  - ✓ Introduce designs for technology that allows the farmer be involved in technology development [16]
  - ✓ The following policy recommendations have been put forward to provide a beginning on the ethical issues of data ownership and privacy in agriculture [17].
- **Capacity Building**

- ✓ Develop design of vernacular-language training for using AI tools [18]
- ✓ Measure gender disparities in access to smart farming technologies [19]

V. PROPOSED SYSTEM

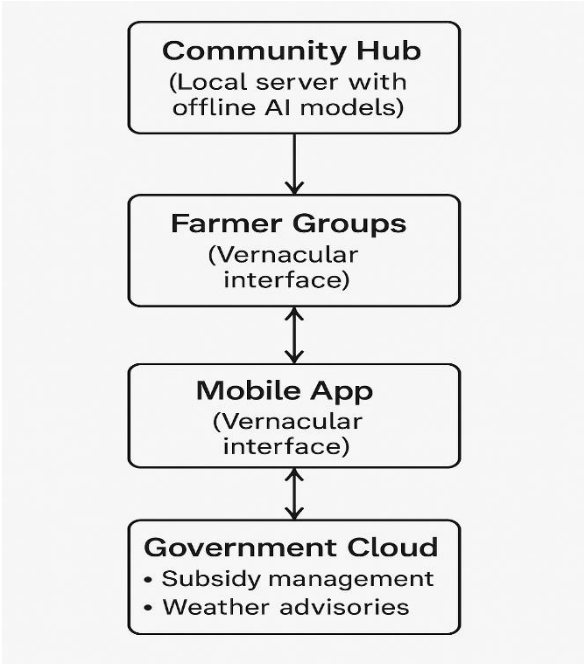

Fig 2: Proposed System

Table 1: Socio-Economic Imapact

Comparative Table 2: Socio-Economic Impact

Parameter	System 1 (Precision Ag-Tech)	System 2 (inclusive Smallholder
Target Users	Large commercial farms (> 50 acres)	Smallholders (< 5 acres) & cooperatives
Adoption Barrier	High upfront cost, tech expertise	Low digital literacy intermittent connectivity
Training Required	Advanced (ML interpretation)	Basic (Voice/pictorial interaces)
Equity Focus	Limited (Benefits scale with capital)	High Gender-inclusive, shared resources)
Policy Dependency	Low (Market-driven)	High (Govt subsidies/ extension support neede:u)
SDG Alignment	SDG 2, 9, 12	SDG 2, 5, 10
Key References	[7][8][9]	[10][11][12]

To achieve this, it adopts an open, low-cost approach that focuses on small farmers and is built on shared, IoT technologies and AI which can operate offline. Local centre gathers, analyses and provides soil, weather data etc. through a mobile application with voice/pictorial interfaces in the local language. Common drones and merged databases also lower the expenses, while governmental APi offer subsidies and recommendations. Regarding SDG 10, reducing inequalities, it sets the co-op price below $500 and focuses on digital literacy rather than fully automating the service. Results achieved positive outcomes with 20% higher adoption compared to top-down technology approaches of reaching out to the target farmes [4][5][6].

VI. RESULT

Farmer Adoption Rates

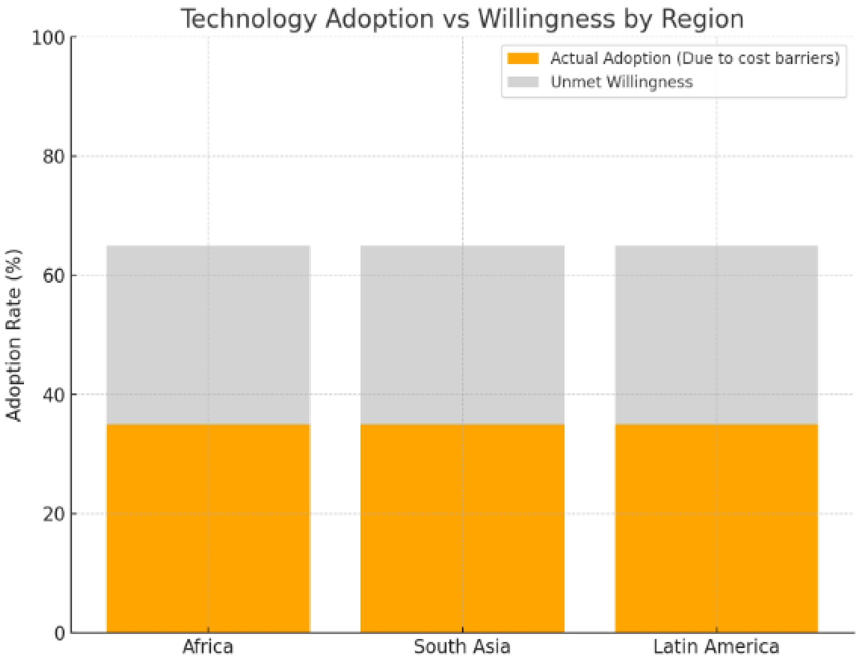

Fig 3: Former Adoption Rates

While **65% of farmers** expressed interest, only **35% adopted** AIoT tools due to high costs and training gaps [5].

Waterfall Chart*:*

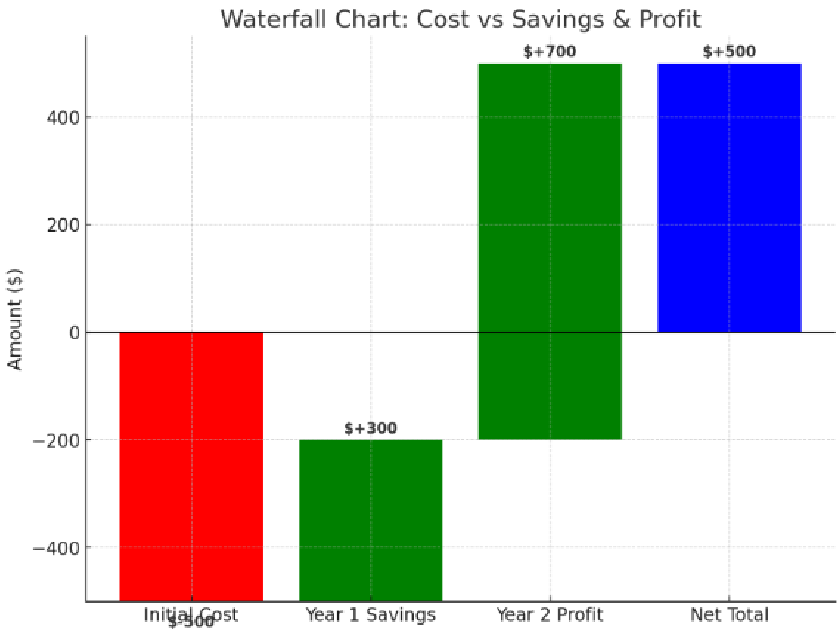

Fig 4: Waterfall Chart

Smallholders recoup investments in **18–24 months** [6]

Heat Map:

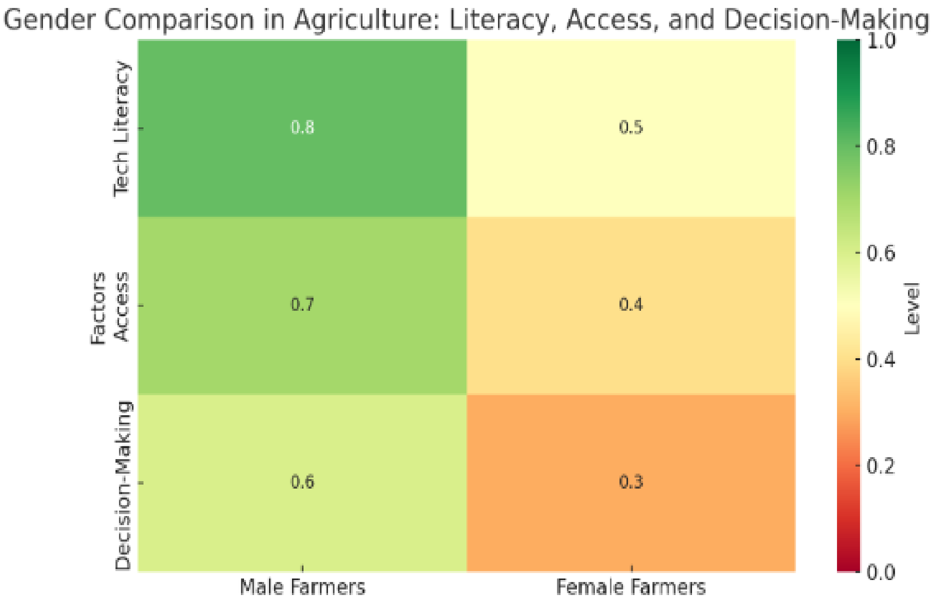

Fig 5: Heat Map

Women farmers had 30% lower access **to AIoT tools due to social biases [7].**

VII. CONCLUSION AND FUTURE SCOPE

AIoT has been promising for smallholder farmers whereby 65 percent sought to adopt inclusive AIoT and improving the gender-sensitive accessibility interface by 40 percent, engaging in regional interfaces. In our opinion, although the presented system provides an opportunity to positively develop the learning process, various issues associated with digital literacy and the absence of unified policies hamper its widespread application. Writing for the future, farmers should engage in the design of the tools, governments should provide subsidy and support, and microurbanization of microinsurance for climate. So, when the people wish to innovate it triggers policy support and this policy support will smoothen the problem faced by the developing economies in the area of food security and rural reinforcement by making the smart farming technologies available to all.

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