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Challenges and Opportunities of Adopting Smart Technologies in Smallholder Agroforestry

Gawande Vaishnav Santosh[1], D Kazhiphro[2*] and Gurpreet Singh[3]
[1]M.Sc. (Ag) Agroforestry, Department of Agronomy, Banaras Hindu University, Varanasi, U.P., India.
[2*]Teaching Associate, FGI, College of Agricultural Sciences, Hengbung, Kangpokpi, Manipur- 795106, India.
[3]Ph.D. Scholar, Department of Agriculture, Guru Kashi University, Talwandi Sabo, Punjab, India.
[*]**Corresponding email address:** Kazhiphro23@gmail.com
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Abstract

Agroforestry systems, which combine trees with crops and animals, are critical for increasing farm resilience, biodiversity, and smallholder farmers' livelihoods. With the growing consequences of climate change, land degradation, and resource constraint, smart agriculture technologies provide new potential to increase agroforestry production and sustainability. Remote sensing, smartphone apps, Internet of Things (IoT) sensors, and decision support systems are all digital tools that may help farmers manage complicated agroforestry systems more effectively. However, smallholder use of these technologies is still restricted due to economic, technical, and social obstacles. This article addresses the major problems and potential related with the use of smart technology in smallholder agroforestry systems, as well as approaches for promoting inclusive and sustainable digital transformation.

Keywords: Agroforestry, smart agriculture, digital technologies, climate-smart agriculture

Introduction

Agroforestry is widely recognized as a sustainable land-use system in which agricultural crops, trees, and, in some circumstances, animals coexist on the same piece of land. It boosts soil fertility, water efficiency, biodiversity, and diversifies smallholder farmers' income sources. Despite the environmental benefits, sustaining agroforestry systems is complex due to the interaction of various components.

Smart agricultural technology has emerged as a viable tool for improved farm management. Remote sensing, mobile advisory services, drones, and sensor networks are some of the technologies that can help farmers monitor soil health, crop development, tree performance, and climate risks. While these tools have great potential for agroforestry, their use by smallholder farmers is inconsistent.

Opportunities of Smart Technologies in Agroforestry

- **Managing climate risks:** Farmers may use weather forecasting systems and climate advisory applications to anticipate droughts, heat stress, and excessive rains. This is especially useful in agroforestry systems, where trees and crops react differentially to climatic changes**.**
- **Improved farm monitoring:** Remote sensing and satellite pictures enable large-scale monitoring of crop vigor, tree canopy cover, and soil moisture. This enables farmers to make quick decisions about watering, trimming, and fertilizer management.
- **Access to information and advisory services:** Farmers may use mobile phones to get real-time updates on pest control, tree species selection, and market prices. Farmers, academics, and extension workers may all share knowledge more easily thanks to digital platforms.
- **Market linkages and traceability:** Digital technologies promote market access by giving pricing information, linking producers and buyers, and allowing for traceability of agroforestry goods such as fruits, wood, and non-timber forest products.
- **Enhanced Resource Use Efficiency:** IoT-based soil and water sensors help optimize irrigation and nutrient use. Efficient resource management reduces costs and improves sustainability in water-scarce regions.

➢ **Challenges in Adopting Smart Technologies**

- **Poor Infrastructure:** Limited access to reliable internet, electricity, and mobile networks in rural areas restricts the use of digital tools.
- **High Initial Costs:** Smart devices, sensors, and subscription-based digital services often require upfront investments that are unaffordable for many smallholder farmers.
- **Limited Digital Literacy:** Many farmers lack the technical skills needed to operate smart technologies effectively. This gap is more pronounced among elderly farmers and women.
- **Data Ownership and Privacy Issues:** Farmers may hesitate to share farm data due to concerns about data misuse, lack of transparency, and unclear ownership rights.
- **Complexity of Agroforestry Systems:** Agroforestry systems are diverse and location-specific. Smart technologies designed for monocropping systems may not easily adapt to the complexity of tree–crop interactions.

➢ **Bridging the Gap: Strategies for Wider Adoption**

To encourage smart technology adoption in smallholder agroforestry, many techniques are required:

- Strengthening rural digital infrastructure.
- Participatory technology development with farmers.
- Low-cost, regionally tailored technology for small farms.

• Capacity development and digital training programs for farmers

• Supportive policies and financial incentives, such as subsidies and credit programs.

Public-private partnerships and farmer cooperatives can also help scale smart agroforestry systems.

Future Outlook

The future of smart agroforestry lies in the combination of low-cost sensors, artificial intelligence, and mobile-based advising services suited to smallholder requirements. Open-source platforms and community-driven data collecting can help to increase accessibility. As digital inclusion grows, smart technology can enhance agroforestry's role in climate resilience, food security, and rural livelihoods.

Conclusion

Smart technologies have considerable prospects for improving the productivity, sustainability, and resilience of smallholder agroforestry systems. However, barriers to wider adoption include cost, infrastructure, expertise, and system complexity. Addressing these hurdles requires inclusive design, capacity building, and supporting policy. Smart technology, by integrating digital innovation with the reality of smallholder farming, can help unlock agroforestry's full potential for sustainable development.

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