Ethical Imperatives and Governance Architectures: Implementing Frameworks for Data Sovereignty, Privacy, and Security in Digital Agriculture Systems

Dr. Md Taj Uddin [1*], Dr. M Wakilur Rahman [2]

[1] Professor, Department of Agricultural Economics, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh
[2] Department of Agricultural Economics, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh

* Corresponding Author: **Dr. Md Taj Uddin**

Article Info

P-ISSN: 3051-3421
E-ISSN: 3051-343X
Volume: 03
Issue: 01
Received: 18-07-2022
Accepted: 20-08-2022
Published: 22-09-2022
Page No: 46-50

Abstract
The rapid proliferation of digital agriculture, encompassing precision farming, Internet of Things (IoT) sensors, and artificial intelligence (AI), has transformed agricultural production into a data-intensive enterprise. While these technologies promise enhanced sustainability and productivity, they generate vast amounts of sensitive data, raising critical concerns regarding ownership, privacy, and control—collectively termed data sovereignty. This article examines the urgent need for robust ethical and governance models to manage agricultural data responsibly. The aim is to analyze and propose frameworks that safeguard stakeholder rights, particularly those of farmers, within the digital ecosystem. The study delves into core ethical principles such as fairness, transparency, accountability, and informed consent, which must underpin data collection and usage. It further evaluates governance structures, including technical standards, access control mechanisms, and policy instruments at national and international levels, designed to enforce data sovereignty and security. Key applications in responsible data management are discussed, focusing on secure precision agriculture operations, trustworthy AI decision-support systems, and equitable value-sharing models. The conclusion underscores that integrating these ethical and governance frameworks is not merely a regulatory compliance issue but a foundational prerequisite for achieving sustainable, equitable, and socially acceptable digital transformation in agriculture. Ensuring farmer-centric data governance is essential for fostering trust, encouraging adoption, and realizing the long-term sustainability benefits of digital farming technologies.

Keywords: Data Sovereignty; Digital Agriculture Ethics; Agricultural Data Governance; Farmer Data Privacy; Precision Farming Security; Responsible Innovation

Introduction

Importance of data in digital agriculture

Digital agriculture represents a paradigm shift, leveraging data from satellites, drones, in-field sensors, and farm machinery to optimize decision-making. This data-driven approach enables precise resource management, predicts yields, detects pests and diseases early, and enhances supply chain transparency [4, 5]. The economic and environmental potential is significant, promising reduced input use, increased resilience, and improved profitability. Consequently, agricultural data has become a highly valuable asset, central to innovation and competitive advantage.

Risks of data misuse and challenges to sovereignty

However, this datafication introduces profound risks. Data generated on-farm often flows to multiple third-party actors, including technology providers, agribusinesses, insurers, and financial institutions, creating complex data ecosystems. Questions of who owns the data, who can access it, for what purposes, and who derives economic benefit remain largely unresolved [6, 7].

Farmers, particularly smallholders, risk becoming mere data subjects rather than data owners, potentially facing disadvantages in markets, loss of privacy, and increased vulnerability to surveillance and exploitative contracts. This erosion of control is the core challenge to data sovereignty—the principle that stakeholders, including nations and individuals, should have authority over their digital information [8].

Scope of the article

This article focuses strictly on the ethical, legal, and governance frameworks necessary to ensure data sovereignty, privacy, and security within digital agriculture. It avoids tangential technological domains to concentrate on the policy and structural mechanisms required for responsible data stewardship. The scope encompasses the analysis of ethical principles, the design of governance models, their practical application in digital farming systems, and an examination of persistent challenges and future directions.

Ethical Principles and Frameworks

Fairness, transparency, accountability, and privacy

An ethical foundation for digital agriculture must be built upon established principles. Fairness requires equitable treatment of all stakeholders, preventing data misuse that could lead to unfair market manipulation or discrimination against certain farmers [9]. Transparency is crucial; data practices, including collection methods, algorithms used for analysis, and data-sharing agreements, must be clear and understandable to farmers [10]. Accountability mandates that entities handling agricultural data are responsible for their actions and for remedying harms caused by data breaches or misuse. Privacy, a subset of data sovereignty, protects personally identifiable information and sensitive farm operations from unauthorized access [11].

Consent mechanisms and farmer-centric approaches

Informed, specific, and dynamic consent is a cornerstone of ethical data collection. Moving beyond simplistic "click-wrap" agreements, ethical frameworks advocate for granular consent mechanisms that allow farmers to choose what data is shared, with whom, for what duration, and for what specific purposes [12, 13]. Farmer-centric approaches position the farmer as the primary rights-holder of data generated from their assets and operations. This empowers them to negotiate data-sharing terms and participate in value creation, aligning with the concept of agency in data governance [14].

Standards for responsible data collection

Operationalizing these principles requires technical and procedural standards. Data minimization (collecting only what is necessary), purpose limitation (using data only for specified reasons), and data security-by-design are critical standards [15]. Ethical frameworks also promote interoperability standards that allow data portability, enabling farmers to switch service providers without losing access to their historical data, thus reducing vendor lock-in and fostering competition [16].

Table 1: Key principles and standards for ethical data governance in agriculture

Principle	Core Tenet	Operational Standard/Manifestation
Fairness	Equitable treatment and benefit-sharing	Anti-discrimination clauses in contracts; equitable value distribution models.
Transparency	Clear, understandable data practices	Readable privacy policies; explainable AI (XAI) for algorithms; open data catalogs.
Accountability	Responsibility for actions and harms	Clear liability frameworks; audit trails for data access and use.
Privacy	Protection from unauthorized intrusion	Data anonymization/pseudonymization; robust access controls.
Consent	Informed and specific permission	Granular, tiered consent interfaces; dynamic consent management platforms.
Sovereignty	Authority over data	Farmer-owned data repositories; clear ownership definitions in law.

Data Sovereignty and Governance Models

Ownership, storage, and access control

Governance models translate ethical principles into enforceable structures. A primary issue is defining legal ownership of complex datasets derived from multiple sources (e.g., farmer-provided land, manufacturer-provided sensor). Models range from recognizing farmers as de facto owners to creating formalized data rights or stewardship licenses [17]. Technologically, sovereignty can be enhanced through federated data storage (where data remains on-farm or within a trusted local server) and strict access control protocols using authentication and encryption [18]. Data cooperatives or trusts are emerging governance models where farmers collectively control and manage their data, bargaining from a position of strength [19].

National and international regulatory frameworks

Policy and regulation are essential backstops. At the national level, some countries are enacting agricultural data-specific legislation, while others rely on general data protection laws (e.g., GDPR in the EU, which applies to personal farm data) [20, 21]. These frameworks enforce rights like access, rectification, erasure, and portability. International efforts, such as the FAO's *Ethics in Digital Agriculture* guidelines and the OECD's work on agricultural data, seek to harmonize principles, but binding global treaties on data sovereignty are absent [22, 23]. Table 3 provides a comparative analysis.

Integration with digital agriculture platforms

Effective governance must be embedded within the digital platforms themselves. This involves designing user interfaces that facilitate granular consent, implementing automated compliance checks for data processing, and using blockchain or other distributed ledger technologies for immutable audit trails of data transactions [24, 25]. Governance models must be agile enough to integrate with diverse platforms, from simple IoT dashboards to complex AI-driven farm management systems.

Table 2: Data types, ownership rights, and stakeholder responsibilities in digital agriculture

Data Type	Exemplary Sources	Primary Rights-Holder	Key Stakeholder Responsibilities
Farm Operational Data	Yield maps, planting dates, input applications	Farmer / Farm Operator	Provide transparent T&Cs; ensure secure storage; enable data export.
Machine-Generated Data	Telematics from tractors, combine performance	Contested (Farmer/Manufacturer)	Clarify ownership via contract; allow diagnostic access to farmers.
Environmental Sensing Data	Soil moisture, satellite imagery, weather stations	May be multi-party (Farmer, Service Provider)	Define licensing agreements; respect spatial privacy.
Derived/Analytic Data	Predictive models, prescription maps	Often Service Provider (depends on contract)	Ensure algorithmic transparency; share insights/benefits with data originator.

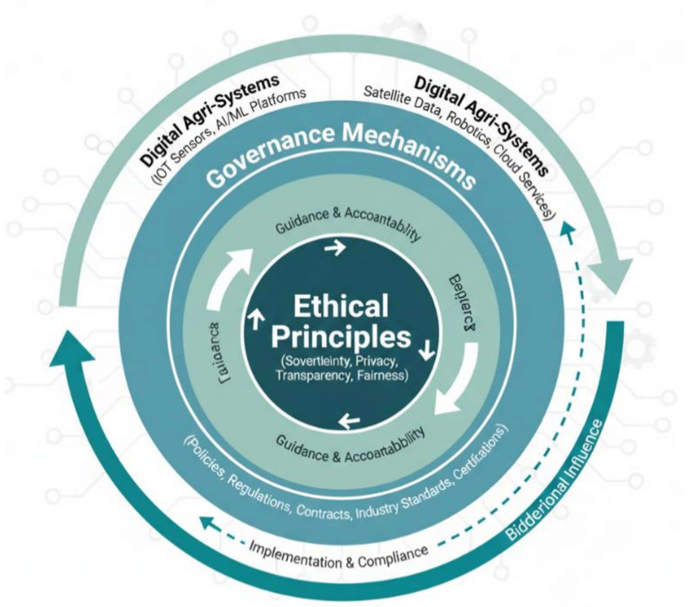

Fig 1: Conceptual framework for ethical and governance models in digital agriculture data management

Applications and Implications

Precision farming, AI, and IoT deployment

Ethical governance directly impacts the application of core technologies. In precision farming, secure data handling ensures that variable-rate application maps remain confidential, protecting a farmer's competitive edge. For AI and machine learning, ethically sourced and governed training data is vital to prevent biased algorithms that could systematically disadvantage certain farm types or regions [26]. IoT deployments must be designed with security-by-design to prevent vulnerabilities that could lead to operational disruption or data theft [27].

Risk mitigation and sustainable technology adoption

Robust frameworks mitigate key adoption risks. They build trust, which is the single largest factor influencing farmer uptake of digital tools [28]. By ensuring privacy and fair benefit-sharing, governance models reduce the fear of exploitation. This responsible adoption pathway is critical for realizing the sustainability benefits of digital agriculture, as it encourages widespread use of technologies that optimize water, fertilizer, and pesticide use, aligning environmental and data ethics [29].

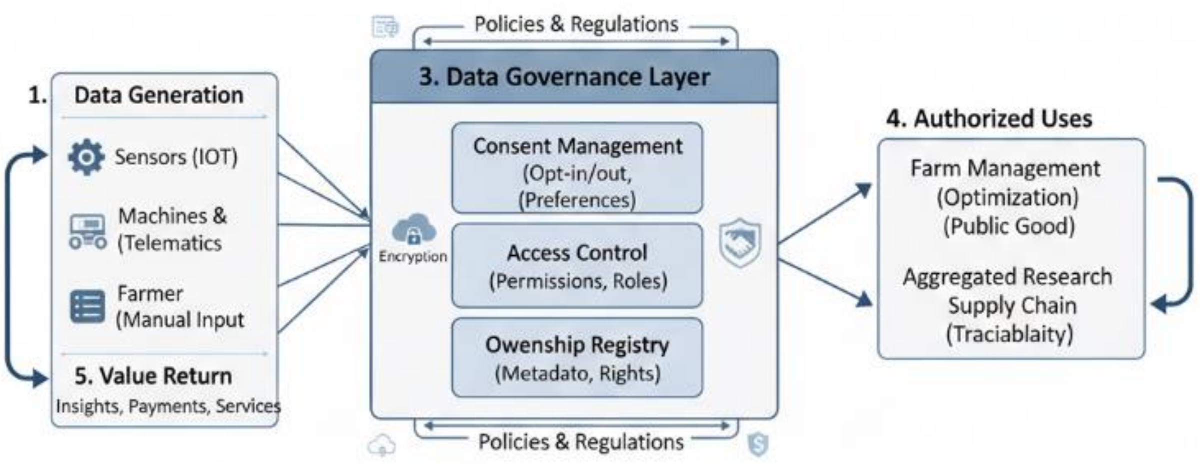

Fig 2: Flow of data collection, ownership, access, and consent mechanisms in precision farming

Challenges and Future Perspectives

Policy gaps, technological limitations, and scalability

Significant challenges persist. Policy gaps are widespread, with many countries lacking specific agricultural data laws, creating legal uncertainty [30]. Technologically, achieving true interoperability between different vendor platforms remains difficult, hindering data portability [31]. Scalability of models like data cooperatives is untested, especially in regions with limited digital infrastructure. Furthermore, the power asymmetry between large agri-tech corporations and individual farmers complicates the enforcement of ethical contracts [32].

Emerging trends in ethical and secure digital agriculture

Future trends point towards more sophisticated governance tools. The use of smart contracts on blockchains could automate consent and value-sharing agreements [33]. Privacy-enhancing technologies (PETs), such as federated learning (where AI models are trained on decentralized data without it leaving the farm), offer promising technical solutions to the sovereignty-privacy dilemma [34]. There is also a growing push for farmer-centric data valuation models to quantify and compensate for data contributions [35].

Table 3: Comparative analysis of national and international policies on agricultural data sovereignty

Jurisdiction/Initiative	Key Focus	Strength	Limitation
European Union (GDPR)	Protection of personal data (incl. farm operator data)	Strong individual rights (access, erasure, portability); high enforcement.	Does not specifically address non-personal farm operational data.
United States (Patchwork)	State-level initiatives (e.g., Iowa's SF 576), industry-led codes (Ag Data Transparent)	Flexibility; promotes innovation.	Lack of federal law creates inconsistency; voluntary codes lack enforcement.
FAO Ethics Guidelines	Holistic ethical principles for digital agriculture	Comprehensive; globally recognized; emphasizes equity.	Non-binding; requires national translation into law/policy.
Data Cooperatives (Model)	Collective farmer ownership and bargaining	Empowers farmers; reduces asymmetry; enables pooled data value.	Legal structure complex; requires high farmer organization and trust.

Table 4: Advantages and limitations of implementing ethical frameworks in digital agriculture systems

Aspect	Advantages	Limitations / Challenges
Trust & Adoption	Increases farmer confidence and willingness to adopt digital tools.	May be perceived as burdensome, slowing initial technology rollout.
Market Equity	Prevents monopolistic data control; fosters fairer competition.	Powerful incumbents may resist changes that diminish their data advantage.
Innovation Quality	Ensures AI/analytics are trained on diverse, ethically-sourced data, reducing bias.	Strict consent/data minimization could limit dataset size for some research.
Compliance	Creates clear rules, reducing long-term legal risk for companies.	Implementation costs (legal, technical) can be high, especially for SMEs.
Sustainability	Aligns data practices with sustainable development goals (SDGs).	Measuring direct causal link between data governance and sustainability outcomes is complex.

Conclusion

The sustainable future of digital agriculture is inextricably linked to responsible data governance. Without ethical frameworks and robust governance models that prioritize data sovereignty, privacy, and security, the digital transformation of agriculture risks exacerbating inequalities, eroding trust, and undermining its own sustainability potential. This analysis underscores that technical solutions alone are insufficient; they must be guided by farmer-centric principles of fairness, transparency, and accountability. The path forward requires a multi-stakeholder effort: policymakers must craft clear and specific regulations, technology developers must embed ethical principles into system design, and farmers must be empowered as active participants in the data value chain. Implementing these frameworks is a complex but necessary endeavor to ensure that digital agriculture benefits are distributed equitably and contribute to a resilient and sustainable global food system.

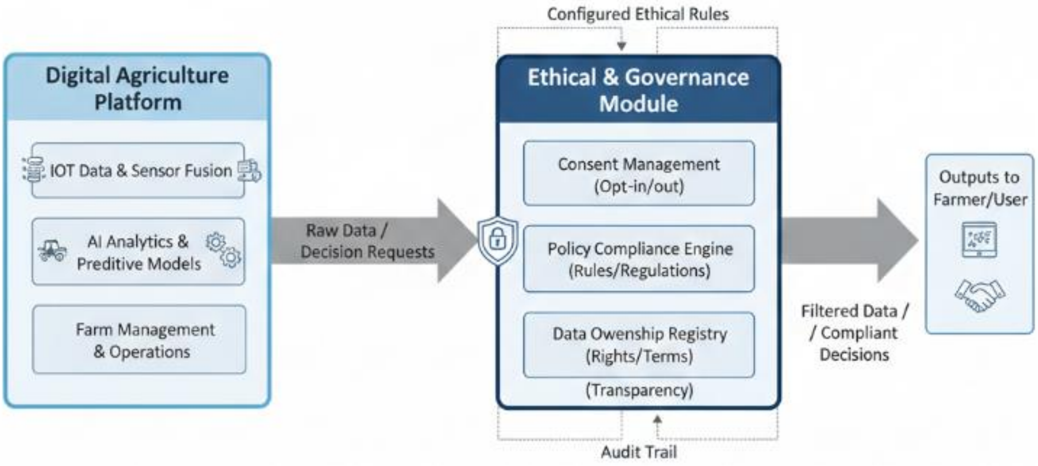

Fig 3: Integration of ethical frameworks with digital agriculture platforms and decision-support systems

References

1. Wiseman L, Sanderson J, Zhang A, Jakku E. Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming. NJAS: Wageningen Journal of Life Sciences. 2019;90–91:100301.
2. Carbonell IM. The ethics of big data in big agriculture. Internet Policy Review. 2016;5(1):1–13.
3. Jakku E, Taylor B, Fleming A, et al. "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in smart farming. NJAS: Wageningen Journal of Life Sciences. 2019;90–91:100285.
4. Wolfert S, Ge L, Verdouw C, Bogaardt MJ. Big data in smart farming: A review. Agricultural Systems. 2017;153:69–80.
5. Eastwood C, Klerkx L, Ayre M, Dela Rue B. Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. Journal of Agricultural and Environmental Ethics. 2019;32(5–6):741–768.
6. Clapp J, Ruder SL. Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. Global Environmental Politics. 2020;20(3):49–69.
7. Ryan M. The social and ethical impacts of artificial intelligence in agriculture: Mapping the agricultural AI literature. AI and Society. 2022;37(4):1501–1518.
8. Hummel P, Braun M, Tretter M, Dabrock P. Data sovereignty: A review. Big Data and Society. 2021;8(1):1–15.
9. Lioutas ED, Charatsari C, De Rosa M. Digitalization of agriculture: A way to solve the food problem or a trolley dilemma? Technology in Society. 2021;67:101744.
10. Binns R, Van Kleek M, Veale M, Lyngs U, Zhao J, Shadbolt N. "It's reducing a human being to a percentage": Perceptions of justice in algorithmic decisions. In: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. New York: ACM; 2018. p. 1–14.
11. Nyst C, Falcao L, Ryan N. The right to privacy in the digital age. Journal of Human Rights Practice. 2022;14(3):874–902.
12. Mittelstadt BD. From individual to group privacy in big data analytics. Philosophy and Technology. 2017;30(4):475–494.
13. Steinke J, van Etten J, Ceccarelli T. Consent and credit: Farmer data rights in the digital age. Development in Practice. 2022;32(5):685–699.
14. Klerkx L, Rose D. Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? Global Food Security. 2020;24:100347.
15. Micheli M, Ponti M, Craglia M, Berti Suman A. Emerging models of data governance in the age of datafication. Big Data and Society. 2020;7(2):1–15.
16. International Organization for Standardization. ISO 23586:2022 Agriculture — Data exchange and interoperability. Geneva: ISO; 2022.
17. Duncan E, Glaros A, Ross DZ, Nost E. New but for whom? Discourses of innovation in precision agriculture. Agriculture and Human Values. 2021;38(4):1181–1199.
18. Ferrag MA, Shu L, Yang X, Derhab A, Maglaras L. Security and privacy for green IoT-based agriculture: Review, blockchain solutions, and challenges. IEEE Access. 2020;8:32031–32053.
19. Gurumurthy A, Bharthur D. Digital democracy: In search of a governance model for data. Bangalore: IT for Change; 2019.
20. European Union. Regulation (EU) 2016/679 (General Data Protection Regulation). Official Journal of the European Union; 2016.
21. Griffin TW, Mark TB, Ferrell S, Janzen T, Ibendahl G. Farm data: Ownership and protections. Milwaukee: Agricultural and Applied Economics Association; 2018.
22. Food and Agriculture Organization of the United Nations. Ethics in digital agriculture. Rome: FAO; 2022.
23. Organisation for Economic Co-operation and Development. Digital opportunities for better agricultural policies. Paris: OECD Publishing; 2019.
24. Kamilaris A, Fonts A, Prenafeta-Boldó FX. The rise of blockchain technology in agriculture and food supply chains. Trends in Food Science and Technology. 2019;91:640–652.
25. Torky M, Hassanein AE. Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges. Computers and Electronics in Agriculture. 2020;178:105476.
26. Leslie D. Understanding artificial intelligence ethics and safety. London: The Alan Turing Institute; 2019.
27. Shafi U, Mumtaz R, García-Nieto J, Hassan SA, Zaidi SAR, Iqbal N. Precision agriculture techniques and practices: From considerations to applications. Sensors. 2019;19(17):3796.
28. Klerkx L, Jakku E, Labarthe P. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS: Wageningen Journal of Life Sciences. 2019;90–91:100315.
29. Zhang A, Baker I, Jakku E, Llewellyn R. Accelerating precision agriculture to decision agriculture: The needs and drivers for the present and future of digital agriculture in Australia. Canberra: Australian Centre for International Agricultural Research; 2022.
30. Shepherd M, Turner JA, Small B, Wheeler D. Priorities for science to overcome hurdles thwarting the full promise of the digital agriculture revolution. Journal of the Science of Food and Agriculture. 2020;100(14):5083–5092.
31. Sykuta ME. Big data in agriculture: Property rights, privacy and competition in ag data services. International Food and Agribusiness Management Review. 2016;19(A):57–74.
32. Fraser A. Land grab/data grab: Precision agriculture and its new horizons. Journal of Peasant Studies. 2019;46(5):893–912.
33. Lin Y-P, Petway JR, Anthony J, Mukhtar H, Liao S-W, Chou C-F, et al. Blockchain: The evolutionary next step for ICT e-agriculture. Environments. 2017;4(3):50.
34. Kaissis GA, Makowski MR, Rückert D, Braren RF. Secure, privacy-preserving and federated machine learning in medical imaging. Nature Machine Intelligence. 2020;2(6):305–311.
35. Fielke S, Taylor B, Jakku E. Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. Agricultural Systems. 2020;180:102763.