BLOCKCHAIN STRATEGY FOR TRANSPARENT AND SUSTAINABLE AGRICULTURAL GOVERNANCE: A PRISMA-GUIDED CONTEXT ANALYSIS

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Abstract

This study critically investigates the strategic potential of blockchain technology as a policy innovation instrument for enhancing institutional transparency, operational efficiency, and sustainability within Thailand's public agricultural sector. While technical applications have been widely documented (Demestichas et al., 2020), limited scholarly attention has been directed toward blockchain's institutional and governance utility (Bustamante et al., 2022) and its role in empowering marginalized stakeholders (Omanwa, 2023). To address this lacuna, a qualitative meta-synthesis of 49 peer-reviewed studies (2014–2024) was conducted, guided by the PRISMA framework and structured through the PICO (Population, Intervention, Comparator, Outcomes) model. Findings indicate that blockchain significantly reinforces institutional trust (96 percent), facilitates decentralized oversight (88 percent), and enhances traceability within agri-food supply chains (58 percent), thereby mitigating challenges such as subsidy misallocation and fragmented data governance. These capabilities are congruent with Sustainable Development Goals (SDGs) 12, 13, 15, and 16 through mechanisms including tamper-proof recordkeeping and automated smart contracts. To promote scalable adoption, the study advocates for integrating blockchain into public-private agricultural partnerships through regulatory harmonization, infrastructure development, and capacity-building initiatives. Additionally, the establishment of a Blockchain Governance Unit is proposed to coordinate cross-agency alignment. This study reconceptualizes blockchain as a strategic enabler of institutional reform and offers actionable insights for embedding emerging technologies into SDG-aligned governance ecosystems.

Keywords: Blockchain Strategy, Agricultural Governance, Sustainable Development Goals, SDGs, Public Sector Innovation, Supply Chain Transparency, Blockchain Adoption

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1. INTRODUCTION

Thailand, as a prominent global agricultural producer, is endowed with extensive natural capital, ecologically diverse farming systems, and a geostrategic position within the international agri-food supply chain. Notwithstanding these intrinsic advantages, the sector continues to face entrenched inefficiencies, ranging from erratic production capacities and absent quality standards to escalating input costs and chronic farmer indebtedness. These systemic impediments constrain economic advancement and imperil the long-term viability of rural livelihoods.

In response, the Thai government has institutionalized sustainable agricultural development as a national imperative within its 20-Year Strategic Framework (2017–2036) and the National Economic and Social Development Plan, emphasizing productivity enhancement, cost rationalization, and rural economic resilience (Chaudhuri et al., 2023; Ministry of Agriculture and Cooperatives [MOAC], 2024).

At the center of this policy recalibration is the Ministry of Agriculture and Cooperatives (MOAC), which has pursued agricultural governance reform through the strategic deployment of digital technologies. Among these, blockchain has emerged as a particularly salient innovation due to its decentralized infrastructure, immutable ledger systems, and verifiable data provenance (Kshetri, 2021). Yet, despite growing attention, existing discourse remains largely technocentric, with limited interrogation of blockchain's operationalization within broader strategic frameworks, particularly Thailand's 20-Year Digital Economy and Society Development Plan and its alignment with Sustainable Development Goals (SDG) oriented agricultural policy, notably SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production).

This raises a critical research question:

RQ1: How can blockchain be operationalized not merely as a technological intervention, but as a strategic mechanism for institutional and policy transformation in agriculture?

This study seeks to address this analytical lacuna by examining blockchain's capacity to recalibrate agricultural governance through its integration into institutional reform agendas. Specifically, it interrogates blockchain's role as a strategic enabler of institutional realignment, policy coherence, and digital modernization consistent with SDG imperatives. Its immutable, tamper-resistant architecture facilitates real-time monitoring, automated smart contracts, and cross-sectoral transparency, mechanisms with potential to mitigate subsidy fraud, streamline agri-trade, and bolster compliance regimes (Balcerzak et al., 2022). These affordances position blockchain as a pivotal instrument within MOAC's modernization agenda, particularly in advancing financial inclusion, supply chain accountability, and environmental stewardship.

Methodologically, the study employs qualitative meta-synthesis, anchored in the PRISMA protocol and structured via the PICO (Population, Intervention, Comparator, Outcomes) framework, to ensure analytical coherence and contextual depth. Rather than relying on conventional pattern categorization, the analysis adopts a context-sensitive lens to interrogate the interface between blockchain innovation, governance dynamics, and strategic policy instrumentation within Thailand's agri-institutional landscape. This approach facilitates a comprehensive understanding of blockchain's practical relevance as a governance mechanism and clarifies its wider implications for institutional adaptation and SDG-aligned policy integration.

Research objectives are as follows:

1) To critically assess the transformative potential of blockchain technology in reshaping agricultural governance within the framework of Thailand's national digital economy policy and broader strategic developmental blueprints.

2) To conduct a comprehensive synthesis of international scholarly work through PICO and context analysis methodologies, aiming to derive actionable, policy-relevant insights on the integration of blockchain technology in public sector agricultural governance.

3) To identify and rigorously analyze the critical success factors and systemic barriers, including governance-related, infrastructural, and regulatory challenges, that impede the effective implementation of blockchain technology within the public agricultural domain.

4) To formulate robust, evidence-driven guidelines for the strategic adoption of blockchain technology, designed to enhance institutional transparency, operational efficiency, and long-term sustainability within Thailand's agricultural sector.

5) To critically evaluate the alignment between blockchain applications and SDGs, specifically in the context of agricultural governance, with a focus on policy integration and sustainability-oriented strategies within Thailand's socio-economic and environmental context.

The rest of the paper is structured as follows. Section 2 offers a critical synthesis of extant literature on blockchain applications in agricultural governance, with emphasis on Thailand and comparative insights from developing economies. Section 3 delineates the methodological architecture, detailing the meta-synthesis and context analysis frameworks that ensure analytical coherence. Section 4 presents findings across social, economic, and technological dimensions, highlighting blockchain's multifaceted governance impacts. Section 5 engages in strategic discussion, articulating policy implications for Thailand and peer contexts. Section 6 concludes with a synthesis of core insights, acknowledgment of limitations, and recommendations for future research trajectories.

2. LITERATURE REVIEW

This literature review is structured into three interrelated subsections, each designed to illuminate the interdisciplinary nature and policy-relevant dimensions of blockchain adoption in the agricultural sector. The first subsection delineates the conceptual and behavioral foundations that inform the diffusion of emergent technologies within institutional ecosystems, drawing upon theoretical insights from innovation studies and behavioral economics. The second subsection critically surveys global trajectories and strategic applications of blockchain technologies that are explicitly aligned with the SDGs, offering comparative perspectives from peer developing economies to contextualize Thailand's position within the global policy landscape. The third section interrogates the Thai case specifically, analyzing the strategic orientation of the MOAC and assessing the institutional readiness and adaptive capacity necessary for effective blockchain integration.

2.1. Theoretical foundations and adoption frameworks of blockchain in agricultural governance

Blockchain, or distributed ledger technology (DLT), constitutes a decentralized, cryptographically secured infrastructure that inscribes immutable data entries, thereby augmenting transparency, accountability, and transactional trust. Initially conceptualized by Nakamoto (2008) through Bitcoin, blockchain systems operationalize consensus protocols such as Proof-of-Work (PoW), Proof-of-Stake (PoS), and practical Byzantine Fault Tolerance (pBFT) to ensure secure, decentralized validation. These systems are typologized into public, private, and consortium blockchains, each offering distinct trade-offs in accessibility, scalability, and governance control. In agriculture, blockchain has been applied across domains, land registries, digital identity, supply chain traceability, foregrounding its utility in strengthening governance efficacy and institutional trust, particularly in support of SDG 9 (Industry, Innovation, and Infrastructure) and SDG 16 (Peace, Justice, and Strong Institutions).

In Thailand, blockchain is increasingly framed as a strategic lever for public sector transformation. It enables policy innovation by recalibrating regulatory architectures, facilitates service innovation through digital access expansion, and drives administrative modernization via reengineered operational workflows (Thai Parliament, 2024). Thus, blockchain is reconceptualized not as a technical add-on but as a catalytic enabler of institutional modernization and SDG-congruent development.

Structured change management paradigms are vital in steering such transitions. While Lewin's foundational three-phase model (unfreeze–change–refreeze) provides an initial lens, its linearity renders it less suited to volatile policy environments. In contrast, Kotter's 8-Step Model offers an iterative and politically attuned framework, emphasizing urgency creation, stakeholder mobilization, and cultural anchoring. The ADKAR (Awareness, Desire, Knowledge, Ability and Reinforcement) model introduces a micro-level behavioral lens, centering on readiness, awareness, and reinforcement, critical for engaging both administrators and agricultural actors. Importantly, these frameworks gain added relevance when applied across diverse stakeholder groups, ranging from national policymakers and subnational agencies to farmers, cooperatives, and technology vendors, each with distinct roles, incentives, and adoption thresholds. Complementarily, Rogers' Diffusion of Innovations and the Technology Acceptance Models (TAM and UTAUT) elucidate adoption dynamics shaped by perceived usefulness, usability, and social norms.

The intersection of behavioral dispositions and institutional architectures emerges as a critical determinant of blockchain adoption trajectories. While behavioral models elucidate motivational logics at the micro level, institutional frameworks assess macro-level governance readiness. Misalignments between these strata may hinder implementation, underscoring the need for cohesive digital strategies, stakeholder alignment, and cross-sectoral coordination, principles integral to SDG 16.

In operationalizing these theoretical foundations, this study employs a systematic research synthesis methodology. The PRISMA protocol and PICO framework guide study selection and analytical structuring (Moher et al., 2009). A qualitative meta-synthesis aggregates findings across disciplinary terrains, while context analysis interrogates the interface between blockchain innovation, governance modalities, and SDG-aligned targets. As Mudjisusatyo et al. (2024) contend, triangulated methodological designs offer a robust epistemological lens for assessing blockchain's institutional salience, particularly in advancing the normative and operational mandates of SDG 9 and SDG 16.

2.2. Blockchain for sustainable development: Global practices and strategic pathways

The SDGs constitute a normative global policy framework aimed at steering technological innovation and institutional reform toward inclusive, resilient, and sustainable trajectories. In agriculture, blockchain has emerged as a catalytic enabler of multiple SDG targets, particularly SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 16 (Peace, Justice, and Strong Institutions). Through its decentralized design, blockchain facilitates traceability, transparency, and data integrity across agri-food value chains, enhancing governance, empowering decentralized actors, and strengthening systemic resilience (Shang & Price, 2019; Kumar et al., 2020).

Global applications illustrate blockchain's utility in public sector innovation. Azevedo et al. (2023) show its efficacy in enhancing financial governance via transparency and corruption mitigation. In India, smart contracts have improved subsidy disbursement efficiency (Yadav et al., 2023), while Vietnam's dairy sector uses automated payments to reduce disputes and foster trust (Ministry of Information and Communications, 2024; Trang & Tan, 2020). These applications resonate with Thailand's context, where inefficiencies and trust deficits undermine subsidy effectiveness.

In public procurement, blockchain enhances procedural equity and reduces transaction costs. Balcerzak et al. (2022) and Chaudhuri et al. (2023) highlight smart contracts' role in mitigating fraud risks. Cambodia's BlocRice initiative, which surpasses traditional Fair Trade models, demonstrates how blockchain enhances traceability and reduces administrative burdens (Trang & Tan, 2020), advancing SDG 16 by reinforcing institutional accountability.

Blockchain also fortifies agricultural supply chains and data infrastructures. Adewusi et al. (2023) and Marzuki (2018) underscore its role in reducing redundancy, streamlining logistics, and securing data flows. Pilots in Vietnam, Indonesia, and Colombia have improved food safety, product authentication, and smallholder market access (Ibrahim et al., 2024; Omanwa, 2023; Kshetri, 2021), thereby contributing to SDG 10 (Reduced Inequalities) and SDG 17 (Partnerships for the Goals).

In land governance, blockchain facilitates tamper-proof, verifiable land records. Estonia and Georgia serve as global models, while pilots in India, Ghana, and Vietnam have reduced disputes and strengthened tenure security (Chaudhuri et al., 2023; Marzuki, 2018; Shang & Price, 2019). These developments are especially relevant to Thailand, where smallholder land rights remain fragmented.

To enable effective adoption, several countries have introduced blockchain strategies. Vietnam's 2024–2030 roadmap emphasizes agri-sector applications and regulatory sandboxes (Oxfam International, 2019), while India prioritizes food system security and investment flows (Chaudhuri et al., 2023). Zheng et al. (2025) argue that successful deployment depends on institutional coherence, infrastructure readiness, and regulatory clarity, interlocking variables equally pivotal for Thailand's agricultural transformation.

2.3. Thailand's digital agriculture strategy and institutional capacity for blockchain adoption

Thailand's MOAC occupies a pivotal position in catalyzing agricultural transformation through the strategic deployment of digital innovations. As articulated in the National Agricultural and Cooperative Strategy (2023–2032), MOAC identifies blockchain and the Internet of Things (IoT) as critical enablers for enhancing real-time productivity monitoring, supply chain transparency, and operational efficiency. These initiatives are directly aligned with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production), particularly through their contributions to resource optimization and institutional performance enhancement.

To translate this digital vision into actionable policy, MOAC has formulated a multi-tiered implementation framework via its 5-Year Operational Plan (2023–2027), integrating blockchain across key strategic initiatives:

1) Contract farming: Blockchain-enabled smart contracts promote transparency and equity in trade agreements, thereby enhancing market confidence and advancing SDG 12.

2) Agricultural technology 4.0: Blockchain-based traceability systems reinforce export compliance mechanisms and support farmer empowerment through Smart Farmer initiatives (SDG 9).

3) 3S (Safety, Security, Sustainability) Strategy: Blockchain infrastructure contributes to food safety assurance, biosecurity, and land verification—core tenets of SDG 15.

4) Big data integration: Blockchain strengthens policy monitoring, compliance tracking, and data governance capabilities in support of SDG 16.

5) Knowledge platforms: Blockchain-based tools facilitate inclusive capacity-building and the dissemination of sustainable agricultural practices, contributing to SDG 1 (No Poverty).

Notwithstanding recent progress, persistent structural constraints, such as rural connectivity deficits, regulatory ambiguity, and fragmented data ecosystems, continue to impede the scalable implementation of blockchain in Thai agriculture. While MOAC has initiated blockchain literacy programs targeting public officials and farmers, these interventions remain insufficient in addressing deeper institutional inertia.

Sustainable adoption necessitates a governance-centered approach. A comprehensive Blockchain Governance Framework, anchored in enforceable legal mandates, delineated institutional roles, and standardized protocols, is imperative to ensure strategic coherence and regulatory predictability. Moreover, establishing a dedicated Blockchain Coordination Unit within MOAC or the Office of Agricultural Economics would facilitate inter-agency alignment, technical harmonization, and multisectoral collaboration.

These institutional mechanisms are not merely operational add-ons; they are foundational enablers for embedding blockchain within national agri-governance systems. Their integration is essential to align digital transformation with SDG commitments and to enhance the long-term resilience, equity, and responsiveness of Thailand's agricultural policy architecture (Thai Parliament, 2024).

3. RESEARCH METHODOLOGY

3.1. Research design

This study adopts a qualitative meta-synthesis methodology to systematically interrogate secondary data on blockchain deployment in public sector contexts, with particular emphasis on agricultural governance. Meta-synthesis enables the integration of qualitative evidence across heterogeneous sources, allowing for the identification of convergent patterns, theoretical linkages, and context-sensitive insights into adoption dynamics. The study is structured using the PICO model, which ensures analytical coherence (Table A.1, Appendix), and follows the PRISMA protocol to guarantee methodological transparency (Figure A.1, Appendix).

This configuration facilitates an evidence-informed appraisal of blockchain's strategic salience for agri-governance in alignment with Thailand's digital transformation and SDG trajectories. While alternative methods, such as grounded theory or case-based comparison, may yield richer narratives, they often lack policy transferability across governance systems. Given the study's orientation toward institutional architectures and policy integration, qualitative meta-synthesis was selected for its capacity to synthesize interdisciplinary perspectives across varied geographies. When combined with context analysis, this design enables a more granular interrogation of the interface between blockchain technologies, institutional reform logics, and cross-sectoral governance instruments, enhancing the study's relevance to evidence-based policymaking in Thailand's agricultural sector.

3.2. Population and sample

The study population comprises peer-reviewed journal articles, graduate theses, and institutional reports that critically examine blockchain applications within public sector domains, with particular emphasis on the agricultural sector. Relevant literature was systematically retrieved from leading academic databases, Google Scholar, ScienceDirect, IEEE Xplore, and SpringerLink, covering publications from 2014 to 2024.

Search queries employed targeted term combinations such as "Government Blockchain Usage", "Public Sector Blockchain Implementation", "State Blockchain Adoption", and "Blockchain Agricultural Applications" were employed to retrieve a broad yet analytically cohesive body of literature. The initial query yielded 23,576 records, which were refined through PRISMA-based screening procedures, culminating in a final sample of 49 articles that met the study's inclusion criteria.

Selection was guided by three analytical benchmarks: alignment with blockchain adoption in public sector agriculture, relevance to institutional governance frameworks, and applicability to national policy imperatives. A detailed summary of included sources is presented in Table A.3 (see Appendix), providing a transparent foundation for subsequent synthesis and context analysis.

3.3. Sample selection

The sample selection process adhered to a structured, replicable, and methodologically rigorous protocol, delineated across four sequential stages designed to ensure analytical validity and conceptual consistency.

1) *Database search*: Relevant publications were identified through targeted queries guided by the PICO framework, which delineated the conceptual scope and ensured content-focused relevance (Table A.1, Appendix).

2) *Screening phase*: The PRISMA flowchart was operationalized to remove redundancies and assess abstracts for relevance to blockchain's role in public agricultural governance (Figure A.1, Appendix).

3) *Eligibility assessment*: Full texts were evaluated for methodological soundness, institutional relevance, and empirical depth. Studies lacking analytical rigor or situated outside the public sector context were systematically excluded.

4) *Selection criteria*: Final inclusion required studies to 1) conceptualize blockchain as a primary analytical variable; 2) investigate adoption drivers or outcomes within public sector systems; 3) fall within the 2014–2024 publication window.

This multistage filtration architecture yielded a refined sample of 49 studies from an initial pool of 1,084 rigorously assessed articles. The process ensured not only methodological integrity but also captured a diverse spectrum of blockchain applications across governance models, sectoral domains, and strategic policy environments.

3.4. Research instruments

To ensure analytical rigor and methodological transparency, two core instruments were designed to structure data extraction and quality appraisal. These tools were not merely procedural aids but integral components in operationalizing evaluative consistency and comparability of findings across diverse sources.

1) Research Quality Assessment Form: This diagnostic instrument encompasses ten evaluative dimensions, ranging from alignment with research objectives and accuracy of data reporting to methodological transparency and relevance to blockchain governance. Each dimension is rated on a 5-point Likert scale, enabling standardization, mitigating evaluator bias, and enhancing the reliability of quality judgments (Table A.3, Appendix).

2) Research Attribute Recording Form: Adapted from established analytical frameworks (Rani et al., 2023; Mohamed, 2023; Al Shamsi et al., 2022), this tool systematically captures metadata for each publication, including blockchain typology, sectoral application, institutional context, and stakeholder involvement. These data form the empirical substrate for comparative analysis, facilitating the identification of cross-cutting patterns across varying governance architectures (Table A.4, Appendix).

Together, these instruments underpin the study's methodological coherence, enabling both evaluative depth and structural comparability across interdisciplinary and cross-national literatures.

3.5. Data collection

Data collection was conducted through a structured retrieval protocol, anchored in predefined search terms applied across curated academic databases. Manual de-duplication and abstract-level screening ensured alignment with the study's objectives. To uphold methodological integrity and minimize selection bias, two independent meta-synthesis reviewers executed a cross-validation of inclusion decisions, thereby enhancing the consistency and replicability of the sampling process.

Key research attributes, such as publication year, blockchain typology, sectoral domain, and stakeholder classification, were systematically coded using Microsoft Excel. Pivot table analysis was employed to generate frequency distributions, enabling preliminary pattern detection and structured data organization. These outputs provided the empirical foundation for subsequent context analysis, facilitating a multi-dimensional interrogation of blockchain's deployment across institutional settings (Table A.6, Appendix).

3.6. Data analysis

This study adopts a mixed-method analytical strategy that integrates descriptive statistical techniques with context-sensitive qualitative analysis to interrogate the institutional dynamics of blockchain adoption in agricultural governance.

1) Descriptive statistics: Coded attributes, including publication year, blockchain typology, and governance domain, were aggregated to discern temporal patterns, frequency distributions, and recurrent policy-relevant clusters (Table A.6, Appendix).

2) Context analysis: Moving beyond conventional coding approaches, context analysis examines the relational interfaces between blockchain technologies and governance ecosystems. This analytical lens yields a more nuanced and strategic understanding of how blockchain is embedded within policy architectures, institutional mandates, and systemic reform agendas, particularly in relation to Thailand's SDG-aligned agricultural strategy.

The PRISMA protocol was rigorously applied to ensure procedural transparency and analytical replicability, while the iterative process of content review and categorization, conducted using a structured matrix developed in Microsoft Excel, facilitated the identification of latent patterns and policy-relevant linkages (Table A.5, Appendix). These insights were operationalized through a structured Context–SDG Mapping (Table A.7, Appendix), which connects blockchain-enabled governance enhancements, such as transactional transparency, supply chain optimization, and resource efficiency, to specific SDG targets.

By synthesizing PICO-based selection logic, PRISMA-guided methodological rigor, and context-driven analytical depth, the study advances novel insights into blockchain's strategic salience within public agricultural governance. While limited to 49 peer-reviewed studies, the analytical corpus provides a scalable evidentiary foundation for future research on blockchain's role in broader institutional and policy environments.

4. RESULTS

This study employed a PICO-based context analysis to investigate blockchain applications within the public agricultural sector, synthesizing empirical insights from 49 peer-reviewed articles (2014–2024) in accordance with PRISMA guidelines. The analytical process began with the construction of Table A.5 (see Appendix) to systematically extract and categorize key variables. Table A.6 (see Appendix) was then used to examine frequency distributions and identify recurrent patterns. These findings were integrated through Table A.7 (see Appendix), which delineates linkages between blockchain functionalities and specific SDGs.

This integrative approach revealed three dominant contextual domains, social, economic, and technological, each corresponding to Thailand's digital economy vision, agricultural modernization goals, and SDG-aligned policy architecture. The findings underscore blockchain's strategic salience in enhancing transparency, operational performance, and environmental resilience in Thailand's agri-governance landscape.

Social context: Blockchain strengthens institutional transparency, mitigates corruption risk, and fosters stakeholder trust through immutable ledgers and decentralized verification. Among the studies, 96% cited transparency and 94% emphasized equitable data access, particularly in empowering smallholders and enhancing inclusive governance. These affordances directly align with SDG 16 (Peace, Justice, and Strong Institutions) and SDG 10 (Reduced Inequalities), reinforcing accountable and participatory agricultural governance.

Economic context: Blockchain improves agri-food system efficiency by enabling real-time monitoring, IoT integration, and transparent logistics. Specifically, 58% of studies reported enhanced traceability, 94% highlighted IoT-enabled process visibility, and 80% noted gains in data storage efficiency, outcomes tied to SDG 12 (Responsible Consumption and Production) and SDG 8 (Decent Work and Economic Growth). Blockchain thus emerges as a catalyst for sustainable value chains, inclusive market access, and rural economic revitalization.

Technological context: Blockchain facilitates secure, decentralized, and interoperable data ecosystems. All studies (100%) noted secure data storage, and 86% reported reduced redundancy via distributed architectures. These features advance SDG 9 (Industry, Innovation, and Infrastructure) through enhanced system integration. Additionally, carbon tracking (100%) and resource optimization tools (82%) support SDG 13 (Climate Action) and SDG 15 (Life on Land), enabling climate-smart agriculture and adaptive governance infrastructures.

5. DISCUSSION

This section synthesizes how blockchain accelerates Thailand's agricultural transformation across three strategic dimensions: governance, value chain efficiency, and digital infrastructure. Grounded in SDG priorities and national digital policy frameworks, it draws from 49 peer-reviewed studies to illuminate key enabling mechanisms, transparency, automation, and interoperability that underpin inclusive and sustainable reform. Comparative insights from peer-developing economies further demonstrate blockchain's broader policy relevance. The section concludes with strategic implications for research and innovation in digitally enabled agri-governance.

5.1. Social context: Strategic governance for inclusive agricultural transformation

Blockchain functions as a governance-enabling architecture that reinforces institutional transparency, curtails corruption, and fosters stakeholder trust, core tenets of SDG 16 (Peace, Justice, and Strong Institutions). Immutable records (96%) and decentralized oversight mechanisms (88%) emerged as pivotal in strengthening institutional legitimacy, particularly in relation to SDG targets 16.5 and 16.7. In Thailand, the MOAC has piloted blockchain for subsidy management, financial oversight, and equitable data access. Organizational change models such as ADKAR and Kotter's 8-Step underscore the role of stakeholder readiness and leadership alignment in driving digital transitions (Thai Parliament, 2024).

Equally important is blockchain's capacity to foster social inclusion. A majority of studies (96%) identified its role in democratizing information access, empowering smallholders, and promoting equity in agricultural resource distribution, advancing SDG 10.2 (Social Inclusion) and SDG 17.16 (Global Partnerships) (Omanwa, 2023; Bustamante et al., 2022). However, such transitions also raise critical ethical implications. Without safeguards to ensure equitable digital access and data protection, blockchain systems risk reinforcing structural exclusion, particularly among digitally marginalized farming communities. The absence of clearly defined rights over data ownership and use may erode trust and undermine the normative goals of SDG 16. Accordingly, the Blockchain SDG sustainability framework (SF) emphasizes "Digital Equity" and "Ethical Governance" as foundational dimensions for ensuring that technological reform does not exacerbate socio-economic vulnerabilities.

Institutionalizing these outcomes requires a dedicated national blockchain roadmap aligned with SDG 16 and digital governance imperatives. Expanding blockchain literacy among subnational actors, and developing decentralized digital identity (DID) systems, will be key to building trust, enhancing subsidy accessibility, and improving public accountability. These tools not only support procedural fairness but also reinforce data sovereignty and consent-based participation. Thailand's trajectory offers valuable insight for peer economies such as Ghana and India, where governance deficits constrain agricultural modernization (Chaudhuri et al., 2023; Ibrahim et al., 2024). In these contexts, blockchain serves not merely as a digital tool, but as a foundational infrastructure for inclusive, participatory governance, conditioned by systemic coordination, digital capacity-building, and robust ethical safeguards.

5.2. Economic context: Blockchain as a catalyst for sustainable agricultural value chains

Blockchain has emerged as a catalytic mechanism for economic transformation in agriculture by automating procurement, enabling traceable transactions, and enhancing supply chain transparency. Across the literature, 94% of studies cite IoT integration, 80% highlight improvements in data storage, and 58% document gains in logistical traceability. In Thailand, MOAC has leveraged these capabilities to digitize subsidy delivery, reduce inefficiencies, and enhance market transparency, advancing SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production).

Smart contracts enable automatic fund disbursement and real-time resource allocation (Alam et al., 2022; Sengupta & Kim, 2021), while financial verification systems, cited in 96% of studies, strengthen budgetary accountability and support rural resilience (Pranto et al., 2021). These digital mechanisms collectively contribute to more responsive and transparent agri-finance infrastructures.

Scaling such impacts requires regulatory clarity, especially frameworks that incentivize transparent smart contracting and promote interoperability with cross-border systems. On the technical side, modular blockchain infrastructure and API-enabled integration with IoT and mobile platforms are essential, particularly in underserved regions.

From a theoretical standpoint, the economic application of blockchain within agriculture invites a reconceptualization of how digital infrastructures intersect with legacy inefficiencies in market access, pricing asymmetry, and transactional opacity. Existing research has yet to fully operationalize blockchain's role as a system-level disruptor that reconfigures value flows across agri-food networks. Future scholarship must integrate structural economic challenges, such as smallholder marginalization, input dependency, and financial exclusion, into frameworks that account for blockchain-enabled reintermediation, cost-efficiency, and distributed agency. Within the Blockchain SDG SF, these pathways are theorized as transitions from centralized inefficiencies to decentralized equity, warranting further empirical modeling across heterogeneous agricultural systems.

Thailand's experience presents a replicable framework: Vietnam's blockchain-enhanced dairy chains reduced transactional frictions (Trang & Tan, 2020), while India's adoption in public procurement increased fiscal transparency (Chaudhuri et al., 2023). These cases demonstrate how blockchain, when integrated with supportive policy environments and contextualized through robust theoretical lenses, can drive more equitable and efficient agricultural economies.

5.3. Technological context: Digital infrastructure and environmental innovation in agriculture

Blockchain enables decentralized, secure, and interoperable data ecosystems that underpin technological innovation in agriculture. All reviewed studies (100%) cited secure data storage as a core enabler, while 86% highlighted reduced redundancy via distributed ledger architecture (Zhang et al., 2024). In Thailand, MOAC is utilizing blockchain for real-time interagency data exchange, precision agriculture, and land-use verification, supporting SDG 9.1 (Resilient Infrastructure) and SDG 9.5 (Scientific Capacity) (Jaoude & Saade, 2019).

Blockchain-based systems for resource optimization (72%) and environmental monitoring align with SDG 13.2 (Climate Policy Integration) and SDG 15.1 (Terrestrial Ecosystems) (Demestichas et al., 2020; Adewusi et al., 2023). These capabilities position blockchain as a strategic asset in digital environmental governance, particularly within the context of Thailand's Bio-Circular-Green (BCG) economy.

Methodologically, the convergence of findings from 49 studies across 2014–2024 reflects a point of analytical saturation, where the recurrence of key affordances (e.g., secure data storage, interoperability, traceability) signals the emergence of robust patterns that are generalizable across contexts. Rather than relying on thematic frequency alone, this study assessed saturation based on the conceptual redundancy of blockchain functionalities across diverse governance environments and technological deployments. This approach, consistent with the Blockchain SDG SF, reinforces the maturity of the discourse in aligning blockchain with systemic infrastructure reform.

To ensure a scalable impact, Thailand must intensify investment in rural digital infrastructure, broadband, edge computing, and secure data nodes. The convergence of blockchain with artificial intelligence (AI) and IoT will enable automated compliance, real-time environmental monitoring, and precision farming. These integrations not only improve agricultural productivity but also reinforce adaptive capacity in the face of ecological volatility.

Future inquiry should examine blockchain's role in carbon accounting, environmental traceability, and disaster risk governance through computational tools and geospatial analytics. International precedents offer actionable models: Estonia and China have applied blockchain to carbon tracking and disaster preparedness (Treiblmaier & Rejeb, 2023), while Colombia and Vietnam demonstrate its utility in agri-environmental compliance (Kshetri, 2021; Ibrahim et al., 2024). These cases affirm blockchain's transformative potential when embedded within inclusive governance architectures and supported by resilient infrastructure systems, for advancing climate-smart agricultural transitions.

6. CONCLUSION

This study critically examined the strategic role of blockchain in transforming agricultural governance in Thailand, with particular emphasis on its alignment with the SDGs. Through a PICO-based context analysis of 49 peer-reviewed studies (2014–2024), the research identified blockchain's transformative utility across three interlinked dimensions: institutional governance (SDG 16), economic performance (SDGs 8 and 12), and technological–environmental sustainability (SDGs 9, 13, and 15). Thailand's experience, particularly under the MOAC, illustrates blockchain integration via immutable records, smart contracts, and decentralized architectures to resolve inefficiencies in subsidy disbursement, market coordination, and resource allocation. Change management frameworks such as Kotter's 8-step model and ADKAR further underscore the significance of stakeholder readiness and digital literacy in facilitating systemic transitions.

Comparative cases from Ghana, Vietnam, India, and Colombia reaffirm blockchain's wider relevance as a governance reform instrument and a driver of inclusive development, underscoring its applicability beyond the Thai context.

Nevertheless, this study is constrained by its reliance on secondary sources and the absence of empirical field validation. Comparative findings remain illustrative rather than model-derived.

Future research should empirically investigate blockchain's effects on governance metrics, such as subsidy efficiency, income equity, and institutional trust, through field-based methodologies including interviews, surveys, and case studies. Cross-country comparative research can further support policy transferability. Additionally, integrating blockchain with AI, IoT, and geospatial analytics may enhance system resilience. Economic modeling, via cost–benefit or scenario simulations, could guide long-term decision-making. Lastly, future inquiry should explore blockchain's role in Thailand's BCG economy, particularly through green finance and sustainability certification frameworks.

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APPENDIX

Table A.1. PICO framework for research selection

Parameter	***Inclusion criteria***
Population	Keywords: Government, Ministry, Public Sector, State, Agricultural Governance
Intervention	None (No specific intervention applied); studies examining blockchain adoption and integration processes
Comparison	None (No comparison required); studies were selected based on relevance rather than comparative frameworks
Outcome	Blockchain usage, blockchain adoption, blockchain implementation, governance improvements, transparency enhancements

To ensure replicability and methodological transparency, this study employed a structured search strategy guided by predefined inclusion and exclusion criteria.

Search strategy: Academic literature was retrieved from Google Scholar, ScienceDirect, IEEE Xplore, and SpringerLink using targeted keywords, Boolean operators, and controlled vocabulary. The search emphasized blockchain applications in public sector governance, with a specific focus on agriculture.

Inclusion criteria: Eligible studies included peer-reviewed journal articles, graduate theses, and institutional reports published between 2014 and 2024. Studies had to explicitly address blockchain adoption within public agricultural governance and cover related themes such as policy implementation, transparency, data security, and supply chain traceability, ensuring a comprehensive perspective on blockchain's contribution to governance efficiency and sustainability.

Exclusion criteria: Excluded were studies limited to private-sector blockchain use without public governance integration, as well as those lacking empirical rigor or methodological clarity. Opinion pieces, duplicates, and articles unrelated to blockchain-enabled governance were also removed. This approach ensured that only high-quality, substantively relevant sources informed the analysis.

Figure A.1. Summary of research selection following PRISMA guidelines

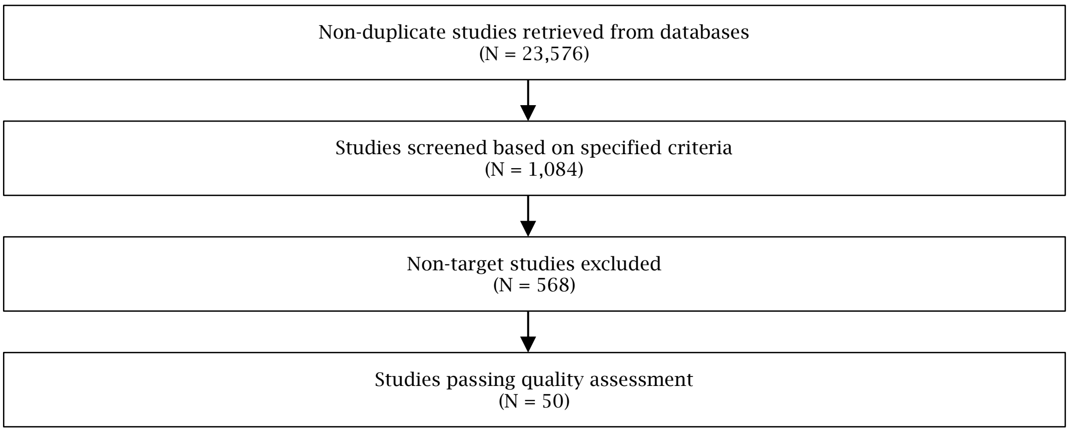

Table A.2. Number of research studies retrieved and approved

Electronic database	***Number of studies retrieved***	***Number of studies selected***	***Number of studies approved***
Google Scholar	17,800	8	3
ScienceDirect	315	74	7
IEEE Xplore	2,230	394	33
SpringerLink	3,231	92	7
Total	**23,576**	**568**	**50**

Table A.3. Research quality assessment form

Aspects of research quality	***Score***				
	0	***1***	***2***	***3***	***4***
Coherence among the research title, issues, and objectives					
Clarity of definitions for specific terminology					
Currency of literature and relevant studies					
Appropriateness of sample selection					
Research design					
Choice of statistical methods/techniques for data analysis					
Clarity in presenting data analysis results					
Accuracy in research conclusions					
Clarity in discussing research findings and providing recommendations					
Overall quality of the research					

Table A.4. Research attribute recording form

Variable	Code	Coded sub-variables
Identification of the article	ID	Amount of 49 articles
Published year	YEAR	Last two digits of year published
Faculty/Field of study	MAJOR	1 = Faculty of Education 2 = Faculty of Sports Science 3 = Faculty of Nursing 4 = Faculty of Science and Technology 5 = Faculty of Humanities and Social Sciences 6 = Faculty of Agriculture 7 = Faculty of Technology 8 = Faculty of Business Administration and Accounting 9 = Faculty of Education 10 = Faculty of Management Science 11 = Faculty of Engineering 12 = Other/not specified
Number of pages	NP	Number of pages
Type of blockchain	TBC	1 = Public blockchain 2 = Private blockchain 3 = Hybrid blockchain
Blockchain attributes	QBC	1 = Decentralization 2 = Transparency 3 = Safety 4 = Flexibility 5 = Efficiency 6 = Sustainability
Blockchain applications	UBC	1 = Financial transactions 2 = Data storage 3 = Transport tracking 4 = Supply chain management
Context of blockchain system usage	CBC	1 = Social context 2 = Economic context 3 = Technological context
Stakeholders in blockchain system usage	SBC	1 = Government agencies 2 = Private sector 3 = Public sector
Research design	TR	1 = Quantitative research 2 = Qualitative research
Research methodology	RM	1 = Documentary study 2 = Exploratory study 3 = Experimental study
Data source	SD	1 = Academic documents 2 = Empirical data 3 = Experiential data

Table A.5. Coding screening (Part 1)

ID	Name	Year	Major	NP	TBC	QBC	UBC	CBC	SBC	TR	RM	SD
1	Islam et al. (2023)	23	4,12	29	1	1,2,3,4,5	2,4,5	1,2,3	1,2,3	2	1,2,3	1
2	Vangipuram et al. (2022)	22	4,11	19	2	1,2,3,4,5,6	2,5	1,2,3	1,2,3	1	1,2,3	2
3	Farooq et al. (2022)	22	10,11	18	2,3	1,2,3,4,5	2,5	1,2,3	1,2,3	2	1,2,3	1
4	Khalil et al. (2022)	22	4	15	1,2	1,2,3,4,5	2,5	1,2,3	1,2,3	1	1,2,3	1,2
5	Ali et al. (2021)	20	10,12	15	1,2,3	1,2,3,4,5,6	1,2,3,4,5	1,2,3	1,2,3	2	1,2	1
6	Kumar et al. (2020)	20	4,10,11	20	2	1,2,3,4,5,6	2,4,5	1,2,3	1,2,3	2	1,2,3	2,3
7	Gohar et al. (2020)	20	4,12	20	1	1,2,3,4,5,6	2,4,5	1,2,3	1,2,3	2	1,2,3	1,2,3
8	Butun and Österberg (2021)	21	4,11	14	1	1,2,3,4,5,6	1,2,3,4,5	1,2,3	1,2,3	1,2	1,2,3	1,2,3
9	Touloupou et al. (2022)	22	7	12	1,2,3	1,2,3,4,5,6	1,2,5	1,2,3	1,2,3	2	1,2,3	1,2
10	Akter Sunny et al. (2022)	22	4,8,10	20	2	1,2,3,4,5,6	1,2,3,4,5	1,2,3	1,2,3	1	1,2	2,3
11	Chukwu and Lalit (2020)	20	7	20	1,2	1,2,3,4,5,6	2,5	1,2,3	1,2,3	2	1,2,3	1,2
12	Akkaoui et al. (2022)	22	7	20	2,3	2,3,4,5,6	2,5	1,2,3	1,2,3	2	1,2,3	1,2
13	Jiang et al. (2022)	22	4,7	20	1,2,3	3,4,5,6	1,2,4,5	1,2,3	1,2,3	1,2	1,2,3	1,2,3
14	Gatica-Neira et al. (2023)	23	8,11	14	3	3,4,5,6	2,5	1,2,3	1,2,3	1	1,2,3	1,2
15	Oruma et al. (2021)	21	4,11	20	3	2,3,4,5,6	2,5	1,2,3	1,2,3	2	1,2,3	1,2,3
16	Mircea et al. (2022)	22	4	19	1,2	1,2,3,4,5,6	2,4,5	1,2,3	1,2,3	2	1,2,3	1,2
17	Marchesi et al. (2022)	22	4	20	2	1,2,3,4,5,6	2,4,5	1,2,3	1,2,3	2	1,2,3	1,3

Table A.5. Coding screening (Part 2)

ID	*Name*	*Year*	*Major*	*NP*	*TBC*	*QBC*	*UBC*	*CBC*	*SBC*	*TR*	*RM*	*SD*
18	Boateng Sifah et al. (2020)	20	4,11,12	12	1	1,2,3,4,5,6	2,5	1,2,3	1,2	2	1,2,3	1,2
19	Jaoude and Saade (2019)	19	12	19	1,2	1,2,3,4,5,6	1,2,4,5	1,2,3	1,2,3	2	1,2,3	1,2
20	Alladi et al. (2019)	19	11,12	14	1,2,3	1,2,3,4,5,6	1,2,4,5	1,2,3	1,2,3	1,2	1,2,3	1,2
21	Bodkhe et al. (2020)	20	11	20	1,2	1,2,3,4,5,6	2,4,5	1,2,3	1,2	1,2	1,2,3	1,2
22	Cagigas et al. (2021)	21	12	22	1,2	1,2,3,4,5,6	2,4,5	1,2,3	1,2,3	2	1,2,3	1,2
23	Ordóñez et al. (2023)	23	11,12	18	1.2	1,2,3,4,5,6	1,2,4,5	1,2,3	1,2,3	2	1,2,3	1,2
24	Yang et al. (2022)	22	13	11	1,2,3	1,2,3,4,5,6	2,5	1,2,3	1,2	2	1,2,3	1,2
25	Dudczyk et al. (2024)	24	11	17	1,2,3	1,2,3,4,5,6	1,2,3,4,5	1,2,3	1,2,3	2	1,2,3	1,2
26	Agarwal et al. (2022)	22	4,11	19	1,2,3	1,2,3,4,5,6	1,2,3,5	1,2,3	1,2,3	1,2	1,2,3	1,2
27	Haga and Omote (2022)	22	11	13	2	1,2,3,4,5,6	1,2,3,4,5	1,2,3	1,2	2	1,2,3	1
28	Musamih et al. (2021)	21	4,11	17	1	1,2,3,4,5,6	1,2,3,5	1,2,3	1,2	2	1,2,3	1,2
29	Chang and Wang (2023)	23	7	14	1,2	1,2,3,4,5,6	1,2,5	1,2,3	1,2,3	1,2	1,2,3	1
30	Al-Shaibani et al. (2020)	20	7	15	3	1,2,3,4,5,6	1,2,5	1,2,3	1,2	1,2	1,2,3	1,2
31	Abugabah et al. (2020)	20	4	18	2	1,2,3,4,5,6	1,2,5	1,2,3	1,2,3	2	1,2,3	1,2
32	Lytras and Şerban (2020)	20	4	12	2	1,2,3,4,5,6	2,5	1,2,3	1,2,3	1,2	1,2,3	1,2
33	Nour et al. (2022)	22	7,11	15	2,1,3	1,2,3,4,5,6	1,2,3,5	1,2,3	1,2,3	1,2	1,2,3	1,2
34	Salman et al. (2019)	19	4	13	1,2	1,2,3,4,5,6	2,5	1,2,3	1,2,3	2	1,2,3	1,2
35	Stefanović et al. (2022)	22	4	20	1,2	1,2,3,4,5,6	1,2,5	1,2,3	1,2	2	1,2,3	1
36	Alam et al. (2020)	20	11	15	3	1,2,3,4,5,6	1,2,5	1,2,3	1,2,3	1,2	1,2,3	1
37	Nookhao and Kiattish (2023)	23	11	17	2	2,3,5,6	5	1,2,3	1,2,3	1	1,2,3	1,2
38	Bennancer et al. (2022)	22	4	15	1,2	1,2,3,4,5	2,5	1,2,3	1,2	2	1,2,3	1,2
39	Addison et al. (2024)	24	4	15	2	2,3,5,6	2,5	1,2,3	1,2,3	1	1,2,3	1,2
40	Ungson and Soorapanth (2022)	22	8	12	1,2,3	1,2,3,4,5	1,4,5	1,2,3	1,2,3	2	1,2,3	1
41	Weigl et al. (2020)	23	12	12	3	1,2,3,4,5,6	5	1,2,3	1,2,3	2	1,2,3	1,2
42	Martínez-Castañeda and Feijóo (2023)	23	7	15	1,2,3	1,2,3,4,5,6	4,5	1,2,3	1,2,3	1,2	1,2,3	1,2
43	Rejeb et al. (2022)	21	4,8,11	32	1,2,3	1,2,3,4,5,6	4,5	1,2,3	1,2,3	2	1,2,3	1
44	Sarnacchiaro et al. (2024)	24	12	33	2,3	2,3,5	5	1,2,3	1,2,3	1,2	2,3	1,2
45	Elisa et al. (2023)	18	4	15	1	1,2,3,4,5,6	2,5	1,2,3	1,2	2	1,2,3	1
46	Zhu et al. (2024)	24	4	15	1,2,3	1,2,3,4,5,6	5	1,2,3	1,2	2	1,2	1
47	Azevedo et al. (2023)	23	12	23	2	1,2,3,5,6	4,5	1,2,3	1,2,3	1	1,2	1,2
48	Jun (2018)	18	12	12	1,2	1,2,3,5,6	5	1,2,3	1,2,3	2	1,2	1
49	Saripalli (2020)	21	12	8	1,2	1,2,3,5,6	5	1,2,3	1,2	2	1,2	1

Note: The table provides a list of 50 studies that were systematically selected and analyzed as part of the meta-synthesis, conducted in accordance with the PRISMA 2020 guidelines. These studies served as the primary data sources for context coding and the development of the conceptual framework in this research.

Table A.6. Pivot table of major and sub-variables

Major and sub-variables	*Frequency*
Year	
2018	2
2019	3
2020	10
2021	6
2022	16
2023	9
2024	4
Major	
Science and technology	24
Technology	9
Business administration and accounting	4
Management science	4
Engineering	18
Other/unspecified	15
NP	
8–12 pages	8
13–17 pages	20
18–22 pages	18
23–27 pages	1
28–33 pages	3
TBC	
Public blockchain	30
Private blockchain	37
Hybrid blockchain	21
QBC	
Decentralization	43
Transparency	48
Security	50
Flexibility	44
Efficiency	48
Sustainability	41
UBC	
Financial transactions	19
Data storage	40
Transport tracking	8
Supply chain management	20
Other uses	47
CBC	
Social context	50
Economic contex	50
Technological context	50
SBC	
Government agencies	50
Private sector	50
Public sector	39
TR	
Quantitative research	19
Qualitative research	43
RM	
Document study	49
Survey study	50
Experimental study	44
SD	
Academic documents	47
Empirical data	36
Experiential data	8

Table A.7. Context-SDG mapping

Context	*Key attributes (QBC)*	*Key applications (UBC)*	*Frequency*	*Relevant SDGs*
Social context	Transparency and efficiency	Public engagement	50	SDG 10, SDG 16
Economic context	Supply chain and efficiency	Financial transactions, IoT	50	SDG 12
Technological context	Data storage and decentralization	Smart contracts, automation	50	SDG 9, SDG 8