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Agricultural Sector Transformation Through A Systematic Literature Review (SLR) Approach: Innovations, Challenges And Future Opportunities

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Abstract: Agricultural transformation is key to addressing the challenges of food security and sustainability in an era of climate change. This article analyses recent developments in agricultural transformation through a systematic literature review (SLR) of 25 articles published between 2017 and 2024. The results identify three main trends: (1) the adoption of digital technologies (precision agriculture, AI and blockchain*), which increase efficiency by 20-45%; (2) sustainable agricultural practices (*agroecology*, regenerative agriculture), which are proven to increase biodiversity by 30%; and (3) innovative evidence-based policies. However, systemic challenges such as the digital divide (only 18% of farmers in Africa have access to technology), land fragmentation and cultural resistance remain key barriers. The study also identified strategic opportunities through agrifintech (300% increase in access to capital), public-private partnerships and bioinformatics for rapid plant breeding. Policy recommendations include strengthening rural digital infrastructure, structured technology literacy programmes, and incentives for inclusive business models. The findings provide a roadmap for stakeholders to accelerate inclusive and sustainable agricultural transformation, with an emphasis on multidisciplinary approaches that combine technical innovation with socio-economic solutions. Further research is needed to assess the long-term impact of technologies on food security and the well-being of smallholder farmers.
Keyword: Transformation of agriculture, smart farming, sustainable agriculture, SLR, agricultural policy

INTRODUCTION

The agricultural sector plays a key role in food security, economic growth and environmental sustainability. According to FAO (2021), agriculture accounts for around 27% of GDP in developing countries and is the source of livelihoods for more than 2.5 billion people. In addition, the sector also contributes to the achievement of the Sustainable Development Goals (SDGs), in particular poverty reduction (SDG 1) and hunger eradication (SDG 2). However, challenges such as climate change, land degradation and rapid population growth threaten the sustainability of conventional agricultural systems. Climate change has disrupted agricultural productivity by increasing the frequency of extreme weather events such as droughts and floods (Moore & Lobell, 2020). Recent studies show that a 1°C increase in global temperature could reduce wheat yields by 6% and maize yields by 7.4% (Zhang, 2020). On the other hand, food demand is projected to increase by 60% by 2050 due to population growth and changing consumption patterns (Altieri, 2018). This calls for an urgent transformation of agricultural practices to ensure long-term food security.

While technological innovations such as precision agriculture and artificial intelligence (AI) are growing rapidly, their adoption is still limited in developing countries. Data from (Scoones et al., 2020) shows that only 15% of farmers in sub-Saharan Africa have access to digital farming tools, compared to 75% in North America and Europe. Infrastructure limitations, low digital literacy and the high cost of technology are the main barriers. As a result, agricultural productivity in many developing regions remains far below its full potential. Intensive agricultural practices that rely on high chemical inputs have led to soil degradation, biodiversity loss and water pollution (Leach et al., 2021). The IPBES report (2019) states that 33% of the world's agricultural land is degraded due to erosion and salinisation. In addition, the agricultural sector is responsible for 24% of global greenhouse gas emissions, mainly due to livestock activities and the use of nitrogen fertilisers (Tubiello et al., 2021). A transition to sustainable agricultural systems is urgently needed to mitigate these environmental impacts.

Policy fragmentation and lack of inter-agency coordination often hamper agricultural transformation (Tubiello et al., 2021). Scoones et al. (2020) found that only 30% of agricultural policies in 15 developing countries explicitly support technological innovation (Scoones et al., 2020). In addition, poorly targeted fertiliser and water subsidies exacerbate inequalities in access to resources (Swinnen &

Kuijpers, 2019). A holistic and inclusive policy approach is needed to drive systemic change. This article aims to analyse the transformation of the agricultural sector through a systematic literature review (SLR) approach to identify trends, challenges and opportunities based on the latest empirical evidence (2017-2024). By mapping the findings of 25 recent studies, the study provides policy and research recommendations to accelerate the adoption of innovations and reduce the gap between developed and developing countries. The results are expected to serve as a reference for stakeholders in designing sustainable and resilient agricultural strategies.

METHODS

Inclusion and Exclusion Criteria

This study used the systematic literature review (SLR) method with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency and reproducibility (Moher et al., 2009). Inclusion criteria included: (1) empirical research articles or reviews published in Scopus/SSCI indexed or reputable journals (Q1-Q3) between 2017-2024; (2) focused on agricultural transformation issues, including technology, policy, sustainability or socioeconomic aspects; (3) available in English or Indonesian; and (4) presented data or analyses that could be extracted for thematic synthesis. Exclusion criteria included studies without peer review, policy reports without empirical analysis, and research that was not relevant to the main question (e.g. focused on non-agricultural sectors). Searches were conducted in Scopus, Web of Science and Google Scholar databases using keywords such as 'agricultural transformation', 'digital farming adoption' and 'sustainable agriculture policy', yielding an initial 1,235 articles, which were then reduced to 25 high-quality studies after duplication, title-abstract screening and full-text eligibility assessment (Liberati et al., 2009).

Data Analysis and Thematic Synthesis

The selected data were analysed using a thematic synthesis approach (Thomas & Harden, 2008) using NVivo 12 software to identify patterns and relationships between themes. The stages of analysis included: (1) open coding to categorise key findings (e.g. technology adoption, institutional barriers); (2) axial coding to link categories to drivers/barriers; and (3) selective coding to construct a holistic narrative. The validity of the findings was strengthened by triangulation across sources and discussions among the research team to reduce bias (Creswell & Poth, 2017). For example, findings on climate change impacts were cross-checked with IPCC reports (20-22) and case studies from different regions (Lobell & Gourdji, 2024). The analysis also included an assessment of study quality using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018) to ensure that only methodologically robust studies were included in the recommendations.

RESULT AND DISCUSSION

Trends In Agricultural Transformation: Integrating Digital Technologies And Sustainable Practices

A synthesis of 25 studies revealed that smart farming and precision agriculture dominate the current discourse on agricultural transformation (Tavakoli et al., 2024). About 60% of the analysed articles show the increasing use of IoT sensors, drones and AI-based systems for real-time crop monitoring. For example, a study in Brazil documented a 22% increase in soybean yields after the implementation of a precision irrigation system (S. S. Santos et al., 2024). However, this adoption is still concentrated in developed countries and regions with adequate digital infrastructure, leaving a large gap in developing countries (Dooyum Uyeh et al., 2023).

Big data analytics and AI algorithms have become the backbone of modern agricultural transformation (Liakos et al., 2018). Research in India has shown that machine learning-based predictive models can reduce the risk of crop failure by 35% by integrating weather, soil and historical production data (Patel et al., 2023). However, the main challenge is the availability of quality data and the ability of farmers to interpret the output of the algorithm (Kamilaris et al., 2019). Recent studies suggest the need for digital literacy training for agricultural extension workers as a bridge between technology and end users (Osimitz & Droege, 2022).

The implementation of blockchain in agricultural supply chains is a rapidly growing trend, especially for export commodities such as coffee and cocoa (Kamilaris et al., 2019). Research in Ethiopia demonstrated that the use of blockchain increased the selling price of organic coffee by 15-20% through transparent traceability of origin (Tadesse et al., 2020). However, the adoption of this technology is still hampered by high implementation costs and resistance from traditional traders who rely on traditional systems (Swann et al., 2023).

The shift towards sustainable agricultural practices, such as agroecology and regenerative agriculture, was highlighted in 40% of the studies analysed (Altieri, 2018). A meta-analysis in Latin America found that agroecology-based polyculture systems increased biodiversity by 30% while reducing reliance on chemical fertilisers (Reséndiz-González et al., 2024). These findings are consistent with the IPCC report (2022), which emphasises the need to decarbonise the agricultural sector through low-emission practices. Policy interventions have proven to be a key driver of transformation in some regions. A comparative study in Southeast Asia found that subsidies for climate-smart agricultural technologies increased the adoption of drought-resistant varieties by 50% (Scoones et al., 2020). However, policies that were not accompanied by technical assistance - as was the case in West Africa - led to a misallocation of resources (Bernard Meka'a et al., 2024). Recent trends show the emergence of innovative business models such as pay-per-use for precision farming tools for smallholder farmers (World Bank, 2022). Pilot projects in Kenya using drone rental systems for fertilisation have reduced production costs by 25% (Muthoni et al., 2023). This approach addresses the affordability of technology while mitigating financial risk for farmers. While significant progress has been made, some challenges remain: 1) Digital divide: 70% of smallholder farmers in the Global South still rely on traditional methods (FAO, 2023); 2) Land fragmentation: Hinders mechanisation in South Asia (Rao et al., n.d.); 3) Short-term political support: Transformation programmes are often interrupted by changes in government (Scoones et al., 2020).

Challenges Of Agricultural Sector Transformation: An Analysis Of Systemic Constraints

Research has shown that the digital divide is a major obstacle to agricultural transformation in developing countries (Dooyum Uyeh et al., 2023). Data from 15 studies show that only 18% of farmers in sub-Saharan Africa have access to digital farming tools, compared to 82% in Western Europe (FAO, 2023). These barriers are compounded by poor internet infrastructure, with rural broadband coverage in South East Asia reaching only 34% (World Bank, 2022). Ironically, technological solutions are often developed for the developed world, making them less suited to the needs of smallholder farmers (Beza et al., 2025). Cross-study analyses show that climate change has reduced global agricultural productivity by 21% since the 1960s (Lobell & Gourdji, 2024). In the case of India, a 1°C rise in temperature reduces wheat yields by 5.2% (Gupta et al., 2022). More worryingly, 73% of farmers in drylands now face uncertain growing seasons (IPCC, 2023). These challenges require systemic adaptation, which is not being addressed by existing technologies (Challinor & Wheeler, 2008).

Research in Java and Bangladesh shows that 68% of farming households manage <0.5 hectares of land (Kamilaris et al., 2019) (Septianto et al., 2021). This extreme fragmentation makes mechanisation uneconomical, with operating costs 40% higher than on larger plots (Takeshima et al., 2023). The land consolidation model in Vietnam was only successful in 12% of cases due to cultural resistance (Nguyen et al., 2023). A meta-analysis of 8 technology training studies found that 61% of farmers aged >50 had difficulty using digital farming applications (Reséndiz-González et al., 2024). In Kenya, only 29% of extension workers are trained in precision agriculture (Muthoni et al., 2023). This phenomenon is creating a 'digital divide generation' that threatens the inclusiveness of the transformation (Aker et al., 2023). A case study in Brazil found that a basic smart farming technology package requires an initial investment of US$15,000/ha - equivalent to 5 years of smallholder income (A. F. Santos et al., 2023) .Innovative financing schemes such as equipment leasing reach only 8% of farmers in the Global South (World Bank, 2023). The 35% risk of technology failure on marginal land further discourages adoption (Markow et al., 2023).

A policy analysis of 12 countries found that 54% of agricultural transformation programmes ended with a change of government (Scoones et al., 2020). The case of Nigeria shows how a change of minister led to the stalling of three agricultural IoT projects worth US$20 million (Ojo et al., 2023). Poor inter-ministerial coordination exacerbated the problem (Swinnen & Kuijpers, 2019). Ethnographic research in Central Java found that 72% of farmers continued to use the prenatal calendar despite the availability of digital weather forecasts. In Mexico, the introduction of blockchain was rejected by 68% of farmers because it disrupted traditional relationships with middlemen (Chaica, 2024). Transformation requires a culturally sensitive socio-technical approach (Eastwood et al., 2023). Longitudinal studies show that the COVID-19 pandemic increased agricultural input costs by 45-120% globally (Reardon et al., 2023). The Ukraine crisis exacerbated the situation, with fertiliser prices in Africa rising by 250% (FAO, 2023). Dependence on global supply chains makes smallholder farmers even more vulnerable (Scott-Barrett et al., 2023).

Opportunities For Transforming The Agricultural Sector: Innovations And Strategies For The Future

Recent studies show that agrifintech can increase smallholder farmers' access to capital by 300% in developing countries. Platforms such as Farm Drive in Kenya have successfully channeled AI-based microcredit to 500,000 farmers with a 97% return rate (Ashraf et al., 2023). Pay-as-you-go models for agricultural technology have also been shown to increase adoption of tetis irrigation from 12% to 38% in 3 years (Cole et al., 2023). This innovation overcomes the traditional problems of lack of collateral and credit history. An analysis of 20 cases in Asia and Africa shows that strategic partnerships between governments, agritech startups and farmers can accelerate technology adoption (Spielman-Sun et al., 2023). A successful example is the eFishery project in Indonesia, which combined IoT with a subscription business model to reach 1.2 million farmers in five years. The triple helix framework (academia-business-government) has proven effective in reducing the risk of technology commercialisation (James et al., 2023).

Advances in CRISPR-Cas9 and genome editing are opening up new opportunities to develop climate-resilient varieties (Zaidi et al., 2024). Research at IRRI has produced flood-resistant, high-yielding rice with a potential yield increase of 45%. Bioinformatics and machine learning now enable plant breeding 10 times faster than traditional methods (Reséndiz-González et al., 2024). Regulatory challenges and public acceptance still need to be overcome to maximise benefits. Global data shows a new wave of agripreneurs aged 18-35 adopting technology (S. S. Santos et al., 2024). Incubation programmes such as the AgriTech Hub in Nigeria have produced 150 start-ups, creating 25,000 jobs. This digital business mindset is transforming agriculture from a subsistence to a high value-added industry (Reardon et al., 2023).

Restoring ecosystems through regenerative agriculture offers a win-win solution for productivity and sustainability (Altieri, 2018). Coffee agroforestry practices in Ethiopia increased farmers' incomes by 35% while increasing soil carbon stocks by 2.5 tonnes/ha/year (Rao et al., n.d.). The agricultural carbon market is projected to be worth $50 billion by 2030, creating new revenue streams Blockchain and IoT enable product traceability from farm to fork (Kamilaris et al., 2019). An implementation in Thailand increased fruit farmers' profit margins by 22% through digital quality certification (Bossio et al., 2020). Agricultural e-commerce platforms such as Twiga Foods in Africa reduced post-harvest waste from 40% to 15% (Beza et al., 2025). This transformation requires data standardisation and system interoperability. Comparative studies show that countries with open data policies in agriculture experience 2.3 times faster productivity growth (Forster et al., 2024). Singapore's regulatory sandbox model for agricultural technology accelerated the commercialisation of innovations by 40% (Liakos et al., 2018). A living lab approach involving farmers in technology development increased adoption from 18% to 63% (Hoogstra et al., 2024).

CONCLUSION

The research found that the transformation of the agricultural sector is driven by three main factors: (1) adoption of digital technologies (smart agriculture, AI, blockchain), (2) sustainable practices (agroecology, regenerative agriculture*), and (3) inclusive policies that support innovation. However, systemic challenges such as the digital divide, land fragmentation and cultural resistance still hinder transformation, especially in developing countries. SLR's findings show that successful solutions are context-specific - a combination of bottom-up (farmer engagement) and top-down (government policy) approaches are needed to create sustainable change.

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