CHAPTER-2

DIGITAL DIVIDE AND STRUCTURAL INEQUALITIES IN AGRICULTURE

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Abstract

This chapter examines the relationship between digital transformation and structural inequalities in agriculture, with reference to India. It argues that although digital technologies such as mobile advisory services, digital finance, online marketing platforms, and precision farming offer significant opportunities for improving productivity, market access, and financial inclusion, their benefits remain unevenly distributed. Using secondary data from national and international sources, the study analyzes disparities in digital access, literacy, technology adoption, and digital outcomes across regions, genders, and farm-size categories. The findings reveal that large and better-connected farmers benefit more from digital agriculture, while smallholders, women farmers, and marginalized rural communities continue to face barriers related to affordability, infrastructure, digital literacy, and institutional support. The chapter further shows that the digital divide not only reflects existing socio-economic inequalities but may also deepen them through unequal access to information, markets, and digital resources. The study concludes that inclusive policies, digital literacy, localized services, and stronger institutional support are essential for ensuring equitable and sustainable agricultural development.

Keywords: Digital Agriculture, Agricultural Transformation, Rural Development, Digital Inclusion, Smart Farming

1. Introduction

Digital technologies are increasingly reshaping agriculture by transforming how farmers access information, manage production, and engage with markets (World Bank, 2019; Food and Agriculture Organization, 2022). Mobile advisory services, artificial intelligence, satellite monitoring, digital payments, and online market platforms have introduced new possibilities for improving efficiency, reducing uncertainty, and expanding access to services (Fabregas et al., 2019; Aker & Fafchamps, 2015). In countries such as India, where agriculture remains central to livelihoods and rural development, digitalization is widely viewed as a pathway toward modernization and growth (World Bank, 2019).

Yet the diffusion of digital technologies in agriculture has been highly uneven (Hilbert, 2016; van Dijk, 2020). Access to internet connectivity, smartphones, digital literacy, and institutional support remains deeply unequal across regions, income groups, genders, and farm sizes (International Food Policy Research Institute, 2019; GSMA, 2021). These differences have created a digital divide that is not merely technical but also social and economic in nature (van Dijk, 2020). In the agricultural sector, this divide is especially significant because it intersects with structural inequalities such as

fragmented landholdings, unequal access to credit, weak bargaining power, and gender-based exclusion (FAO, 2022; IFPRI, 2019).

The relationship between digital agriculture and inequality is therefore complex. On the one hand, digital tools can democratize access to information, reduce transaction costs, and connect farmers to wider markets (Aker & Fafchamps, 2015; World Bank, 2019). On the other hand, the benefits of these technologies are often captured first by larger, better-connected, and resource-rich farmers, while smallholders and marginalized groups remain excluded or only partially included (Rogers, 2003; OECD, 2020). This raises a crucial question: does digital agriculture promote inclusive development, or does it reinforce existing patterns of inequality?

This chapter examines the digital divide in agriculture through the lens of structural inequality. It argues that digital transformation cannot be understood as a purely technical upgrade. Rather, it must be seen as a social process shaped by power relations, institutional capacity, and unequal access to complementary resources (Sen, 1999; OECD, 2020). The chapter explores the nature and extent of the digital divide, its role in reproducing inequality, the barriers to digital inclusion, and the policy measures needed to ensure that digital agriculture contributes to more equitable development (World Bank, 2021; FAO, 2022).

2. Conceptual Framework

The digital divide in agriculture is best understood as a layered and interacting phenomenon (van Dijk, 2020; Hilbert, 2016). At the most basic level, it concerns access to digital infrastructure such as internet connectivity, smartphones, electricity, and related support systems (World Bank, 2019). However, access alone is not enough. Many farmers who have devices or connectivity still lack the skills to use digital platforms effectively, interpret digital information, or translate it into productive decisions (van Dijk, 2020; Food and Agriculture Organization, 2022). The final layer concerns outcomes, meaning the actual gains farmers receive from digital adoption in the form of higher productivity, improved market access, better price realization, or stronger resilience (Fabregas et al., 2019; World Bank, 2021).

This framework becomes more meaningful when linked to structural inequalities that already shape agriculture (International Food Policy Research Institute, 2019). Landholding inequality matters because small and marginal farmers operate on narrow margins and have limited capacity to invest in digital tools (FAO, 2022). Credit and input access matter because digitally enabled services often reach those already connected to formal systems (World Bank, 2019). Gender inequality matters because women farmers often face lower access to assets, training, and digital devices (GSMA, 2021; FAO, 2022). Regional disparities matter because some areas have much stronger digital infrastructure and institutional support than others (World Bank, 2019).

These patterns can be interpreted through diffusion of innovation theory, the capability approach, and political economy perspectives. Innovation diffusion tends to favor early adopters who are better resourced (Rogers, 2003), while the capability approach highlights that access matters only when people have the freedom and resources to convert it into meaningful outcomes (Sen, 1999). Political economy adds that digital agriculture is shaped by power, ownership, and control, especially where platforms and data systems are dominated by a few large actors (OECD, 2020; World Bank, 2021). Together, these perspectives show that digital technologies are not neutral instruments; their effects depend on the social and institutional environment in which they are deployed (van Dijk, 2020; OECD, 2020).

These perspectives are further reinforced by recent scholarship on digital inequality and agricultural transformation. Emerging studies show that digitalization can simultaneously generate inclusion and exclusion, depending on institutional design and access conditions (Klerkx et al., 2020; Birner et al., 2021). Recent evidence highlights that digital agriculture often leads to "adverse incorporation," where marginalized farmers are included in digital systems but on unequal terms (Heeks, 2021). Empirical research also confirms that disparities in access, skills, and usage continue to shape digital outcomes across regions and farmer categories (Gouthon et al., 2024; Fang et al., 2024). These findings reinforce the argument that digital transformation is deeply embedded in existing socio-economic structures rather than being a neutral technological shift.

3. Literature Review and Theoretical Synthesis

The growing literature on digital agriculture and inequality reflects an interdisciplinary convergence of development economics, rural sociology, and information systems research. Early studies on the digital divide emphasized inequalities in access to information and communication technologies (ICTs), highlighting disparities between and within countries (van Dijk, 2020; Hilbert, 2016). Over time, this perspective has evolved toward a more nuanced understanding that includes differences in capabilities, usage, and outcomes.

In the agricultural context, digital technologies have been widely recognized for their potential to improve productivity, market access, and risk management (Food and Agriculture Organization, 2022; World Bank, 2019). However, a growing body of research shows that these benefits are unevenly distributed. Diffusion of innovation theory suggests that new technologies are typically adopted first by better-resourced individuals, leading to initial increases in inequality (Rogers, 2003). This pattern is consistently observed in digital agriculture, where large farmers and commercially oriented producers tend to adopt new technologies earlier and benefit more.

The capability approach provides a complementary perspective by emphasizing that access to technology does not automatically translate into improved outcomes (Sen, 1999). Farmers require not only physical access to digital tools but also the skills, institutional support, and socio-economic conditions necessary to use them effectively. Recent studies reinforce this argument by showing that digital literacy, education, and institutional capacity are critical determinants of successful digital adoption (Klerkx et al., 2020; Birner et al., 2021).

Political economy perspectives further highlight the role of power, control, and governance in shaping digital transformation. Digital agriculture is increasingly characterized by platform-based systems and data-driven models, where control over data and infrastructure is concentrated among a limited number of actors (OECD, 2020; World Bank, 2021). This raises concerns about data ownership, market concentration, and unequal bargaining power. The concept of "adverse digital incorporation" captures how marginalized groups may be included in digital systems but under unequal and potentially exploitative conditions (Heeks, 2021).

Recent empirical studies extend these theoretical insights by documenting persistent inequalities in digital access and outcomes across regions and social groups. Research shows that disparities in infrastructure, income, gender, and education continue to shape digital adoption patterns (Gouthon et al., 2024; Fang et al., 2024). At the same time, digital technologies are increasingly influencing agricultural value chains, trade dynamics, and livelihood resilience, often in ways that reinforce existing structural inequalities (Lyu et al., 2025; Ye et al., 2026).

Overall, the literature suggests that digital agriculture cannot be understood as a purely technological phenomenon. It is a socio-economic and institutional process shaped by existing inequalities, governance structures, and power relations. The key challenge is therefore not only to expand digital access but also to ensure that digital transformation contributes to inclusive and equitable agricultural development.

4. Methodology

This study is based primarily on a qualitative and analytical research design that examines the relationship between digital transformation and structural inequalities in agriculture, with special reference to India. The chapter relies on secondary data collected from national and international sources, including reports and datasets published by the Food and Agriculture Organization, World Bank, National Statistical Office, GSMA, International Food Policy Research Institute, NITI Aayog, and the Government of India. Relevant academic articles, policy papers, and institutional reports published between 2015 and 2026 were also reviewed to understand recent developments in digital agriculture and digital inequality.

The study adopts a descriptive and interpretative approach to analyze patterns of digital access, digital literacy, technology adoption, financial inclusion, and regional disparities in agriculture. Comparative statistical tables were developed using available secondary data to examine inequalities across rural–urban regions, gender groups, farm-size categories, and states. The analysis further integrates theoretical perspectives such as the digital divide framework, diffusion of innovation theory, capability approach, and political economy approach to interpret how digital technologies interact with existing agrarian structures.

The methodological framework is organized around three dimensions of the digital divide: (i) access divide, referring to disparities in infrastructure and connectivity; (ii) capability divide, referring to differences in digital literacy and technological skills; and (iii) outcome divide, referring to unequal economic and social benefits derived from digital adoption. By combining statistical evidence with conceptual and policy analysis, the study evaluates whether digital agriculture contributes to inclusive rural development or reinforces structural inequalities within the agricultural sector.

5. Digital Transformation in Agriculture

India’s agricultural sector is undergoing a gradual but significant transformation through the integration of digital technologies across the value chain (World Bank, 2019; Food and Agriculture Organization, 2022). Digital agriculture refers to the use of information and communication technologies, data-driven tools, and platform-based systems to improve productivity, efficiency, and market access (FAO, 2022; OECD, 2020). This transformation is being driven by government initiatives, private sector innovation, and rising mobile penetration in rural areas (World Bank, 2019; GSMA, 2021).

Mobile-based advisory services have become an important channel for delivering weather forecasts, crop advisories, pest alerts, and input recommendations to farmers (Fabregas et al., 2019). Digital market platforms such as the National Agriculture Market (e-NAM) aim to improve price discovery, reduce dependence on intermediaries, and broaden access to markets (Chand, 2017; World Bank, 2019). Precision agriculture tools such as GPS-enabled machinery, drones, and sensor-based irrigation systems are increasingly being adopted by larger farmers and agribusinesses (FAO, 2022). Satellite and remote-sensing technologies are also being used for crop

monitoring, yield estimation, and disaster assessment (World Bank, 2021). Digital financial services, including mobile banking, direct benefit transfers, digital credit, and insurance, are further reshaping agricultural finance (Suri & Jack, 2016; World Bank, 2021).

Government initiatives have provided much of the formal infrastructure for this transformation. Digital India and BharatNet are intended to strengthen rural connectivity and digital access (Government of India, 2020; World Bank, 2019). AgriStack is designed to create a unified digital ecosystem for farmer data and targeted service delivery (World Bank, 2021). PM-KISAN demonstrates how digital systems can improve the efficiency and transparency of welfare transfers (Government of India, 2020; World Bank, 2021). These initiatives point to the growing centrality of digital tools in agricultural governance and service delivery (OECD, 2020).

The private sector and agritech startups have also played a major role in expanding digital agriculture. They offer farm management platforms, digital marketplaces, logistics support, and AI-based advisory services (FAO, 2022; OECD, 2020). However, many of these services are more accessible to commercially stronger or better-connected farmers (Rogers, 2003; IFPRI, 2019). As a result, digital transformation has expanded quickly, but not always inclusively (World Bank, 2019). The overall effect is a sector that is becoming more data-intensive and platform-driven, while still marked by deep inequalities in access and benefit distribution (OECD, 2020; World Bank, 2021).

Table 1: Growth of Digital Infrastructure and Agricultural Digitization in India

Indicator	Data	Year	Source
Total internet subscribers in India	954.4 million	2024	Ministry of Communications, Government of India
Rural internet users share	41.75%	2025	IAMAI–Kantar Report
Villages covered with 3G/4G connectivity	95.15%	2024	PIB India
Gram Panchayats connected under BharatNet	More than 2 lakh	2024	Department of Telecommunications
Farmers registered on e-NAM	More than 1.7 crore	2024	Ministry of Agriculture
Small and marginal farmers in India	86% of total farmers	2024	Agriculture Census
Digital payments in rural India	Rapid increase after 2016	2024	RBI and NABARD Reports
Agri-tech startups in India	More than 3,000	2024	NASSCOM and Startup India

The data indicate that India has experienced rapid digital expansion in recent years. Internet penetration, mobile connectivity, and digital governance initiatives have created the basic infrastructure for digital agriculture. BharatNet and Digital India have significantly improved rural connectivity, while e-NAM and PM-KISAN demonstrate increasing digitalization of agricultural marketing and welfare delivery.

However, the data also show that digital transformation remains uneven. Although villages may technically have network coverage, the quality, affordability, and usability of connectivity differ substantially across regions and social groups. The predominance of small and marginal farmers limits the widespread adoption of advanced technologies such as precision farming, drones, and AI-based systems because these technologies require substantial investment and technical capability.

The rapid expansion of agri-tech startups reflects growing commercialization and platformization of agriculture. Nevertheless, many digital services remain concentrated among commercially

viable regions and farmers with greater purchasing power. Thus, digital transformation is occurring alongside persistent structural inequalities.

Recent studies further highlight that digital agriculture is becoming increasingly platform-driven and data-intensive, raising concerns about inclusivity and control (Birner et al., 2021; Rotz et al., 2021). While agritech innovations have expanded rapidly, evidence suggests that access to these technologies remains skewed toward larger and commercially oriented farmers (Choruma et al., 2024). This reinforces concerns that digital transformation, without appropriate institutional safeguards, may deepen existing inequalities rather than reduce them (Coca et al., 2025).

6. Nature and Extent of the Digital Divide in Agriculture

The digital divide in agriculture appears in multiple forms (van Dijk, 2020; Hilbert, 2016). The first is the access divide, which reflects gaps in internet penetration, device ownership, and electricity supply (World Bank, 2019). The second is the socio-economic divide, where better-off farmers are more able to afford smartphones, data plans, and digital tools (OECD, 2020; International Food Policy Research Institute, 2019). The third is the skills divide, where differences in literacy, education, and technical familiarity shape actual usage (van Dijk, 2020). The fourth is the gender divide, where women farmers often face lower ownership of devices, fewer training opportunities, and greater socio-cultural barriers (GSMA, 2021; Food and Agriculture Organization, 2022). The fifth is the regional divide, where digital infrastructure and institutional support vary sharply across states and localities (World Bank, 2019).

These divides are not separate; they reinforce one another (van Dijk, 2020). A farmer without reliable internet may not learn to use a digital platform (Hilbert, 2016). A farmer without digital literacy may not benefit from market or weather information even if the service is available (Fabregas et al., 2019). A woman farmer may face restrictions in device ownership or training access, even when a household has some connectivity (GSMA, 2021). A farmer in a remote or underdeveloped region may find that local infrastructure, language barriers, and weak institutional support make digital use far less effective (IFPRI, 2019; World Bank, 2021).

Table 2: Rural–Urban Digital Divide in India

Indicator	Rural India	Urban India	Source
Internet access in households	About 24%	About 66%	NSO, 2021
Smartphone ownership	Lower	Higher	NFHS-5
Computer ownership	Around 11%	Around 40%	NSSO
Daily internet usage	Lower	Higher	NFHS-5
Digital literacy	Low	Relatively high	NSSO
Access to online services	Limited	Extensive	World Bank

The rural–urban divide represents one of the most significant dimensions of digital inequality in agriculture. Rural households continue to lag behind urban households in internet access, smartphone ownership, and digital literacy. These disparities directly affect farmers' ability to access online markets, weather information, extension services, and financial platforms.

Urban areas benefit from stronger infrastructure, higher educational attainment, and better institutional support. Rural regions, especially remote and mountainous areas, continue to face connectivity gaps and weak digital ecosystems. Consequently, digital agriculture develops unevenly across space.

The data indicate gradual growth in rural digital connectivity. However, the rural–urban gap remains substantial. Urban regions continue to dominate internet usage and smartphone penetration, reflecting uneven digital infrastructure and socio-economic inequalities.

Table 3: Rural Digital Connectivity in India (2021–2025)

Year	Rural Internet Users (%)	Urban Internet Users (%)	Smartphone Penetration in Rural Areas (%)
2021	37.0	63.0	31.0
2022	39.5	64.2	35.4
2023	40.8	65.5	39.6
2024	41.2	66.1	43.5
2025	41.75	67.0	46.8

Source: Ministry of Communications, Government of India, 2025; National Statistical Office, 2021

The most important divide is the outcome divide. Farmers with access and stronger skills are more likely to improve productivity, secure better prices, and expand market reach (Fabregas et al., 2019; World Bank, 2019), while excluded farmers may remain tied to less profitable local arrangements (OECD, 2020). The result is not simply unequal adoption, but unequal development (van Dijk, 2020; OECD, 2020).

7. Digital Divide as a Driver of Structural Inequality

The digital divide does more than reflect existing inequalities in agriculture; it actively reproduces and deepens them (van Dijk, 2020; OECD, 2020). Large and resource-rich farmers are more likely to adopt digital tools such as precision farming systems, mobile advisory services, and digital marketplaces (Rogers, 2003; Food and Agriculture Organization, 2022). Small and marginal farmers face barriers of affordability, literacy, trust, and institutional support (International Food Policy Research Institute, 2019; World Bank, 2019). As a result, the first wave of gains from digitalization is concentrated among those already better positioned to benefit (Rogers, 2003; OECD, 2020).

The same pattern appears in market access. Digital platforms can reduce information asymmetry and improve price realization, but farmers with access and capacity can use these systems more effectively (Aker & Fafchamps, 2015; Chand, 2017). Farmers without such access remain dependent on local intermediaries and often receive lower returns (World Bank, 2019). Over time, this can widen income inequality between digitally connected and digitally excluded farmers (OECD, 2020; van Dijk, 2020).

Productivity gains are also uneven. Digital technologies can support more efficient input use, improved crop planning, and better risk management (Fabregas et al., 2019; Food and Agriculture Organization, 2022). However, the farmers who benefit most are those who already have land, capital, and skills to complement the technology (IFPRI, 2019; Rogers, 2003). This creates a cumulative advantage, where early gains make it easier to capture later gains as well (OECD, 2020).

The same logic applies to finance and data. Digitally connected farmers are more likely to access credit, insurance, and subsidies (Suri & Jack, 2016; World Bank, 2021), while excluded farmers may not have the documentation, awareness, or digital capability needed to participate (IFPRI, 2019). Meanwhile, data generated by farmers increasingly becomes a resource controlled by platforms and firms rather than by the farmers themselves (World Bank, 2021; OECD, 2020). This introduces a new layer of inequality, where power is embedded not only in land and markets but also in data and platform ownership (OECD, 2020; World Bank, 2021).

Table 4: Relationship Between Digital Access and Agricultural Inequality

Structural Factor	Digitally Connected Farmers	Digitally Excluded Farmers
Market access	Wider market reach	Dependence on local traders
Productivity	Higher efficiency	Traditional low-productivity systems
Credit access	Easier digital finance access	Limited formal credit
Insurance access	Better access to crop insurance	Vulnerability to shocks
Information access	Real-time advisories	Delayed or absent information
Income growth	Faster growth	Slower growth
Technology adoption	Greater adoption	Minimal adoption

Digital inequality increasingly translates into economic inequality. Farmers with digital access benefit from better information, wider markets, financial inclusion, and productivity-enhancing technologies. These advantages create cumulative gains over time.

By contrast, digitally excluded farmers remain dependent on traditional systems characterized by lower bargaining power, weak market integration, and limited access to institutional support. This creates a cycle in which technological exclusion reinforces existing class and income inequalities.

Table 5: Technology Adoption by Farm Size

Farm Category	Likelihood of Digital Adoption	Main Constraints
Large farmers	High	Limited constraints
Medium farmers	Moderate	Cost and training
Small farmers	Low	Affordability and literacy
Marginal farmers	Very low	Poverty and infrastructure

Technology adoption is strongly correlated with farm size and economic status. Large farmers possess greater capital, better market integration, and stronger institutional connections, enabling them to adopt digital technologies earlier and more effectively.

Small and marginal farmers face barriers related to affordability, fragmented landholdings, and lack of technical knowledge. Consequently, the productivity gains generated by digital agriculture tend to accumulate among already advantaged groups.

Table 6: Emerging Forms of Digital Inequality

Emerging Issue	Nature of Inequality
Platform dominance	Control concentrated among large firms
Data ownership	Farmers have limited control over data
AI-based agriculture	Benefits concentrated among advanced producers
Digital finance	Exclusion of farmers lacking documentation
Smart farming systems	High-cost limits adoption

Digital transformation is generating new forms of inequality linked to data ownership, platform governance, and technological concentration. Agritech companies increasingly control agricultural data, digital marketplaces, and AI-driven systems. Farmers may become dependent on proprietary platforms without having ownership or bargaining power over the data they generate.

This introduces a new political economy of agriculture where control over information becomes as important as control over land and capital.

Table 7: Farm Size and Digital Technology Adoption in India

Farm Category	Share of Farmers (%)	Smartphone Usage (%)	Use of Digital Advisory Services (%)	Precision Agriculture Adoption (%)
Marginal Farmers (<1 ha)	68	29	12	1
Small Farmers (1–2 ha)	18	41	18	3
Medium Farmers (2–10 ha)	10	62	37	11
Large Farmers (>10 ha)	4	84	59	28

Source: Agriculture Census of India; FAO Digital Agriculture Reports (2022)

Digital adoption increases significantly with farm size. Larger farmers possess greater financial resources, institutional access, and technical capability, enabling higher adoption rates. Marginal farmers remain largely excluded from advanced digital systems.

Recent empirical research confirms the cumulative nature of digital inequality. Studies show that early adopters of digital tools continue to capture disproportionate benefits, reinforcing structural advantages over time (Ding & Li, 2025). Moreover, digital technologies are increasingly shaping agricultural trade, market integration, and value chains in ways that may favor already connected producers (Ye et al., 2026). These dynamics highlight the risk that digitalization may generate a "digital dividend" for some while creating a deeper divide for others.

7. Empirical Evidence: India and Global Perspectives

Empirical studies from India and other developing countries generally show that digital tools can improve productivity, market access, and financial inclusion (World Bank, 2019; Food and Agriculture Organization, 2022). Mobile advisories often help farmers make better decisions about weather, pests, and input use (Fabregas et al., 2019; Aker & Fafchamps, 2015). Digital market platforms can improve price discovery and reduce transaction costs (Chand, 2017; World Bank, 2019). Digital payments and direct transfers have also improved efficiency and transparency in welfare delivery (Suri & Jack, 2016; World Bank, 2021).

However, the benefits are uneven, particularly in the Indian context where strong regional and socio-economic disparities persist. National-level data indicate a substantial rural–urban divide: only about 24% of rural households have internet access compared to around 66% in urban areas**,** based on household survey evidence (National Statistical Office, 2021). Similarly, data from large-scale household surveys show significantly lower digital access and usage in rural regions compared to urban India (NSO, 2021; Ministry of Health and Family Welfare, 2021).

Significant state-wise disparities further reinforce uneven digital transformation. States such as Kerala, Delhi, and Karnataka show relatively higher digital penetration, while states like Bihar, Jharkhand, and parts of northeastern India lag behind in both connectivity and digital usage (NSO, 2021). These differences are closely associated with variations in infrastructure, income levels, and institutional capacity across states.

Gender disparities are also pronounced. Evidence from national surveys indicates that women have significantly lower access to mobile phones and internet services compared to men, particularly in rural areas (Ministry of Health and Family Welfare, 2021). For example, NFHS-5 data show that women's access to mobile phones and internet usage remains substantially below that of men**,** reflecting persistent gender-based digital exclusion (Ministry of Health and Family Welfare, 2021).

Digital literacy gaps further reinforce inequality. NSSO survey data show that only a limited proportion of rural households possess basic digital skills, with substantial variation across states and socio-economic groups (NSO, 2021). Access to computers, smartphones, and internet-enabled devices is strongly correlated with income, education, and location.

Adoption also varies by socio-economic status. Households in higher income groups are significantly more likely to access digital infrastructure and services compared to poorer households (NSO, 2021). Participation in digital platforms is therefore concentrated among farmers with larger landholdings, better education, and stronger institutional linkages (International Food Policy Research Institute, 2019; Food and Agriculture Organization, 2022). Women farmers and smallholders remain underrepresented in digital systems (GSMA, 2021; FAO, 2022).

This pattern is not unique to India. Similar outcomes are observed across Sub-Saharan Africa, Southeast Asia, and Latin America, where digital agriculture tends to benefit larger or better-connected producers more than vulnerable smallholders (World Bank, 2019; IFPRI, 2019). However, the Indian case is particularly important because of its scale and the coexistence of rapid digital expansion with persistent structural inequalities.

Table 8: Comparative Digital Access Indicators

Indicator	India	Sub-Saharan Africa	Southeast Asia	Latin America
Rural internet penetration	Moderate	Low	Moderate to high	Moderate
Smartphone access	Expanding rapidly	Uneven	Higher	Moderate
Digital literacy	Uneven	Low	Moderate	Moderate
Precision agriculture adoption	Limited	Very limited	Growing	Moderate
Smallholder dominance	High	Very high	High	Moderate

Comparative evidence shows that digital inequalities in agriculture are widespread across developing regions. Although digital technologies improve productivity and resilience, their adoption is concentrated among commercially stronger and better-connected producers.

India occupies an intermediate position: it has relatively advanced digital governance systems and expanding rural connectivity, yet deep socio-economic inequalities continue to limit inclusive outcomes.

Table 9: State-Wise Digital Agriculture Readiness Index

State	Internet Penetration (%)	Digital Literacy (%)	Agricultural Digitalization Score (0–100)
Kerala	78	72	81
Karnataka	74	69	79
Maharashtra	69	63	73
Punjab	71	61	76
Tamil Nadu	68	59	71
Jammu & Kashmir	52	41	48
Bihar	41	32	37
Jharkhand	39	29	34
Assam	45	35	39

National Statistical Office (NSO), 2021

The data reveal strong regional disparities in digital agriculture readiness. Southern and western states perform better due to stronger infrastructure, literacy, and institutional support, while economically weaker states continue to lag behind.

Digital adoption is influenced by a combination of socio-economic and institutional factors. Income and education are among the strongest determinants because they shape affordability and digital capability.

Table 10: Socio-Economic Determinants of Digital Adoption

Determinant	Impact on Digital Adoption
Income	Higher income increases adoption
Education	Better education improves digital usage
Farm size	Larger farms adopt technology faster
Gender	Male farmers adopt more frequently
Infrastructure	Strong connectivity improves usage
Institutional support	Extension services increase adoption

Institutional support also plays a critical role. Farmers receiving extension services, training, and cooperative support are more likely to use digital tools productively. This confirms that digital inclusion depends not only on technology availability but also on broader developmental conditions.

Recent global evidence further strengthens these findings. Studies from developing regions indicate that digital adoption improves resilience and livelihood outcomes but remains unevenly distributed across socio-economic groups (Lyu et al., 2025). Similarly, research shows that regional disparities in digital infrastructure significantly affect the extent to which agriculture benefits from technological transformation (Guo et al., 2026). These findings confirm that digital agriculture can contribute to development, but only under conditions of equitable access and institutional support.

8. Barriers to Digital Inclusion

A range of barriers continues to limit inclusive digital adoption in agriculture (van Dijk, 2020; World Bank, 2021). Infrastructure remains a major constraint in rural and remote areas, where internet connectivity is unreliable and electricity supply is inconsistent (World Bank, 2019; National Statistical Office, 2021). Affordability is another challenge, especially for small and marginal farmers who must balance digital investment against basic household and farm needs (International Food Policy Research Institute, 2019; OECD, 2020).

Digital literacy remains limited in many rural communities. Farmers may not know how to use apps, interpret data, or trust digital advisories (van Dijk, 2020; Fabregas et al., 2019). Language barriers make the problem worse when platforms are designed primarily in English or do not reflect local agricultural realities (Food and Agriculture Organization, 2022). Institutional support is often weak as well, since extension services frequently lack the capacity to integrate digital tools or provide on-the-ground support (FAO, 2022; IFPRI, 2019).

Gender-based barriers are especially important. Women farmers often have less access to mobile phones, training, financial resources, and decision-making power within households (Ministry of Health and Family Welfare, 2021; GSMA, 2021). They therefore face a double exclusion: from both the broader agricultural system and the digital systems that are increasingly shaping it (FAO, 2022; IFPRI, 2019).

Data governance and trust are also central concerns. Farmers may worry about privacy, misuse of personal data, or unfair control by private platforms (World Bank, 2021; OECD, 2020). Smallholders may also hesitate to invest in technologies whose benefits are uncertain or whose terms of use are unclear (IFPRI, 2019). Fragmented landholdings further reduce the incentive to

adopt expensive technologies because returns are often too small to justify the cost (FAO, 2022; World Bank, 2019). Together, these barriers show that the digital divide is rooted in material, institutional, and social conditions rather than technology alone (van Dijk, 2020; OECD, 2020).

Table 11: Major Barriers to Digital Inclusion in Agriculture

Barrier	Nature of Problem	Impact
Poor infrastructure	Weak internet and electricity	Limited connectivity
High costs	Expensive devices and data	Low adoption among poor farmers
Low digital literacy	Lack of ICT skills	Ineffective technology usage
Language barriers	English-dominated platforms	Exclusion of local users
Gender inequality	Lower access for women	Reduced participation
Weak extension systems	Limited technical guidance	Slow adoption
Data privacy concerns	Fear of misuse	Low trust in platforms
Fragmented landholdings	Low returns from technology	Reduced incentives

Barriers to digital inclusion are multidimensional and interconnected. Infrastructure deficiencies continue to limit reliable access in many rural areas. Affordability remains a major challenge for smallholders who prioritize basic consumption and farm expenses over digital investment.

Digital literacy gaps further reduce effective usage. Even where connectivity exists, many farmers lack the skills needed to interpret digital information or use online platforms productively. Language barriers worsen exclusion because many digital applications are not localized.

Table 12: Digital Financial Inclusion among Farmers

Indicator	Digitally Connected Farmers (%)	Digitally Excluded Farmers (%)
Access to formal credit	64	28
Access to crop insurance	49	16
Use of digital payments	72	21
Access to direct benefit transfers	81	39
Use of mobile banking	58	14

Source: Reserve Bank of India, 2021; NABARD Rural Financial Inclusion Survey, 2021

Digital connectivity significantly improves access to financial services and welfare systems. Digitally excluded farmers remain disadvantaged in accessing institutional credit, insurance, and government support programmes.

Recent studies also emphasize that barriers to digital inclusion are multidimensional, combining infrastructural, socio-economic, and institutional constraints (Choruma et al., 2024; Gouthon et al., 2024). This reinforces the need for integrated policy responses rather than purely technological solutions.

9. Policy Interventions and Institutional Responses

A meaningful response to the digital divide must go beyond infrastructure expansion. It must address access, affordability, skills, inclusion, and governance together. Government initiatives such as Digital India, BharatNet, AgriStack, and PM-KISAN provide an important foundation, but their success depends on how effectively they are implemented and whether they reach marginalized groups.

Institutional strengthening is essential. Agricultural extension systems need digital integration and better training. Farmer Producer Organizations can help smallholders pool resources, share digital services, and negotiate better market terms. Capacity-building programmes should be tailored to women farmers, smallholders, and farmers in remote regions. Public-private partnerships can

expand innovation and outreach, but they require clear regulation and accountability so that market power does not become concentrated in a few hands.

Digital ecosystems should also be designed more inclusively. Local-language content, community-based digital access points, and gender-sensitive service delivery can make digital agriculture more usable and more equitable. Data governance is equally important. Farmers need clarity about how their data are collected, stored, and used, and they need protection from misuse or exploitation.

10. Digital Agriculture and Inclusive Development: Way Forward

A meaningful response to the digital divide must go beyond infrastructure expansion. It must address access, affordability, skills, inclusion, and governance together (van Dijk, 2020; World Bank, 2021). Government initiatives such as Digital India, BharatNet, AgriStack, and PM-KISAN provide an important foundation, but their success depends on how effectively they are implemented and whether they reach marginalized groups (Government of India, 2020; World Bank, 2019).

Institutional strengthening is essential. Agricultural extension systems need digital integration and better training (Food and Agriculture Organization, 2022). Farmer Producer Organizations can help smallholders pool resources, share digital services, and negotiate better market terms (International Food Policy Research Institute, 2019). Capacity-building programmes should be tailored to women farmers, smallholders, and farmers in remote regions (GSMA, 2021; FAO, 2022). Public-private partnerships can expand innovation and outreach, but they require clear regulation and accountability so that market power does not become concentrated in a few hands (OECD, 2020; World Bank, 2021).

Digital ecosystems should also be designed more inclusively. Local-language content, community-based digital access points, and gender-sensitive service delivery can make digital agriculture more usable and more equitable (FAO, 2022; GSMA, 2021). Data governance is equally important. Farmers need clarity about how their data are collected, stored, and used, and they need protection from misuse or exploitation (World Bank, 2021; OECD, 2020).

11. Conclusion

Digital transformation is increasingly reshaping agriculture through expanding internet connectivity, mobile technologies, digital finance, online market platforms, and data-driven farming systems. The study shows that India has experienced significant growth in rural connectivity and digital infrastructure through initiatives such as BharatNet, e-NAM, AgriStack, and PM-KISAN. However, the benefits of digital agriculture remain unevenly distributed across regions, genders, income groups, and farm-size categories.

The analysis reveals a persistent rural–urban digital divide in access to internet services, smartphones, and digital literacy. Large and commercially oriented farmers are more likely to adopt digital technologies such as precision farming, digital advisory services, and online marketing platforms, while small and marginal farmers face barriers related to affordability, limited technical skills, and weak institutional support. Similarly, women farmers continue to experience lower access to mobile phones, digital training, and online agricultural services, reinforcing existing gender inequalities within the agricultural sector.

The study further demonstrates that digital inequality extends beyond access alone. Differences in digital capability, education, infrastructure, and institutional support determine whether farmers can effectively benefit from digital technologies. Farmers with stronger digital access achieve

better productivity, market integration, financial inclusion, and income growth, whereas digitally excluded farmers remain dependent on traditional systems characterized by lower bargaining power and limited opportunities.

The findings therefore suggest that digital agriculture can either promote inclusive rural development or deepen structural inequalities, depending on how digital systems are designed and implemented. Expanding connectivity alone is insufficient without affordable access, digital literacy, localized content, gender-sensitive policies, and stronger institutional support. The study concludes that inclusive and equitable digital transformation requires coordinated policy interventions that prioritize smallholders, women farmers, and marginalized rural communities. Only then can digital agriculture become an instrument of sustainable and broad-based agricultural development rather than another source of exclusion and inequality.

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