

Food Flow, Farmer Income, and ICT: A Review of Technology-Driven Agricultural Supply Chain Models

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ABSTRACT: Global food systems suffer from inefficiencies that leave up to one-fifth of all food produced lost or wasted, even as hundreds of millions remain food-insecure. Digital technologies (ICT)– from mobile apps and e-marketplaces to IoT and data analytics– are increasingly deployed to make food supply chains more visible, reduce waste, and link smallholder farmers to markets (boosting their incomes). This review synthesizes interdisciplinary literature on ICT in agriculture, with special focus on developing economies (particularly India and Africa). We survey three thematic areas: ICT in agriculture (information access, farm management, extension), market access (e-platforms, price information, direct sales), and food waste (post-harvest losses, supply-chain optimization). Methodological approaches range from econometric field studies (e.g. double-hurdle models) to design-science development of mobile apps and systematic reviews of digital innovations. We tabulate representative models and case studies (Table 1) and include a schematic figure illustrating rural food flows. Overall, the literature shows that mobile platforms and e-market systems can increase price transparency and farmer bargaining power, while sensor and data tools (IoT, AI) optimize logistics and storage to cut spoilage. However, adoption barriers and fragmented evidence highlight research gaps: few studies link technology directly to measured farmer incomes or food-loss reductions over time. We conclude by identifying future directions for integrated, scalable ICT-enabled supply chain solutions.

KEYWORDS: Agricultural supply chains, ICT in agriculture, Food flow, Farmer income, Food waste, Digital marketplaces

I. INTRODUCTION

Smallholder farmers worldwide face volatile prices, uncertain weather, and limited market information. Traditional supply chains often burden farmers with low farm-gate prices and high post-harvest losses, largely benefiting middlemen. Poverty and hunger persist despite global food output “right now, the world produces enough food to nourish every person”. Yet nearly one-fifth of all food produced is lost or wasted, eroding farmers’ potential earnings and global food security. In India, for example, tens of millions of tons of fruits and vegetables spoil yearly due to inadequate cold storage and logistics. Reducing these losses and ensuring efficient food flows (farm -> market -> consumer) could dramatically improve incomes and sustainability. Emerging ICT (Information and Communications Technology) offer new tools to address these challenges. Mobile phones, sensors, and internet platforms now connect even remote farmers to real time price and weather data. Digital marketplaces (e.g. India’s e NAM) link producers and buyers beyond local boundaries. Agricultural apps provide extension advice, market linkages, and even mobile banking. Similarly, novel technologies– from IoT-enabled storage to blockchain traceability– promise to make food flows visible and efficient. Technology can intercept each link of the supply chain to supply data, forecasts, or digital transactions. In this review we integrate findings from academic and applied studies, with emphasis on developing economy cases (India, Africa, Bangladesh, etc.). We first review the themes of ICT in Agriculture, Market Access, and Food Waste, highlighting how each is addressed by technology. We then summarize the research methodologies used (e.g. field

surveys, pilot interventions, systematic reviews), identify gaps in the literature, and conclude with implications for policy and innovation. A comparative table (Table 1) summarizes select ICT-driven supply chain models from the literature.

II. LITERATURE SURVEY

A. ICT in Agriculture

Information asymmetry and inefficient extension are chronic problems in farming. Studies show that mobile phones and apps bridge these gaps by delivering timely data (weather, prices, agronomy) directly to farmers' hands. For instance, Mittal and Mehar (2012) document that rising mobile penetration in India allows custom-tailored agricultural information delivery, helping overcome traditional knowledge limits. Mobile apps provide real-time market prices and weather forecasts, enabling farmers to plan planting and sales decisions. Digital extension— e.g. SMS alerts or video tutorials— scales up knowledge sharing at lower cost than person-to-person outreach. Importantly, resource-management apps use data (soil, moisture, pest alerts) to reduce input waste and optimize yields, contributing to higher productivity and income. ICT also facilitates collaboration and resource pooling. The mobile CHAPONA case in Tanzania illustrates a multi-stakeholder app where farmers, extension agents, and mediators share information via smartphones. After registering on the app's cloud backend, users could post queries, receive advice, and conduct two-way communications. The system was co-designed via participatory design research (Design Science Research), reflecting farmers' needs. The demonstration showed the app reliably disseminated knowledge and was acceptable to users, with observed reductions in "information gaps" between farmers and service providers. This mixed method case highlights how tailored ICT tools can improve the flow of agricultural information along the value chain. More broadly, literature reviews emphasize ICT's crosscutting role in agriculture. Ganeshkumar et al.'s comprehensive review (2017) notes that effective supply chains (enabled by ICT) can "maximize the income" of small farmers. They stress that adequate financing of the supply chain— which makes technologies like internet and mobile networks accessible— is a prerequisite for these benefits. In India's supply networks, introducing digital record-keeping and communications has begun to empower smallholders by improving transparency on inputs and market demand. Overall, ICT in agriculture is used to (a) widen information access, (b) optimize farm operations and inputs, and (c) build farmer networks; all of which set the stage for better food flows and incomes.

B. Market Access

A key barrier for farmers is gaining fair market access. Middlemen often capture most of the value: one Nigeria study found that "real profit goes to the middlemen" who buy at low farm-gate prices and sell at high consumer prices, eroding farmers' returns. Digital models aim to bypass or empower these middlemen by directly linking producers and buyers. For example, e-marketplaces allow farmers to list produce online where multiple buyers can bid. India's National Agriculture Market (e NAM), launched in 2016, is a public pan-India trading portal connecting over 1,000 regulated local markets (mandis) under one network. Farmers and traders across states can access the portal via web or mobile app; it integrates GPS-based mandi locators and electronic scale systems to ensure transparent quality-assessment and pricing. Early reports indicate e NAM enrolls millions of farmers and is reducing intermediation costs by enabling "buyers situated even outside the mandi/state" to bid on local produce. Other examples include private apps and classified platforms. "Mandi Trades" (India) and "Dhaan Mandi" (Bangladesh) let farmers post crops online to reach buyers directly (B2B style). Research in Nigeria confirms that simple ICT tools like mobile phones significantly improve market participation: Nwangwu et al. find that farmers with phones (and even radios) are more likely to engage in staple crop markets, mainly because they can access timely price information and production advice. Likewise, workshops using mobile apps and SMS have achieved improved price-awareness and bargaining: one Tanzania study notes that farmers needed minimal training to use smartphone apps, which provided "speedy flow of information" and high user satisfaction. Moreover, mobile platforms often bundle finance and extension. IJSA (2022) review highlights that linking market data with banking services (mobile wallets, insurance) addresses rural credit gaps. When farmers get paid on the spot via digital payments, they can invest in inputs sooner. These ICT-driven models thus cut transaction costs and share margins more evenly: "By cutting out intermediaries, farmers gain a fair share of the profits while consumers access fresh produce at reasonable prices". In summary, digital marketplaces and apps enhance market visibility (price transparency, buyer networks) for farmers, which studies link to higher farmer incomes and inclusion.

C. Food Waste

Food loss and waste pose both humanitarian and sustainability challenges. According to the World Food Programme, roughly 20 Studies of industry 4.0 applications highlight multiple tech solutions. A systematic review finds that 16 digital technologies (from IoT sensors to blockchain to AI) are being applied at various supply-chain stages to address food loss events. For example, IoT-enabled cold storage and real-time inventory sensors can predict spoilage and optimize harvesting schedules. A 2025 case study in Sustainability shows that IoT and AI significantly cut urban food waste by optimizing inventory control and transportation routes. While that work is in an urban-retail context, the principle applies to farm-to-market chains: better forecasting and automated routing can prevent unsold perishables. Even simpler digital interventions help mobile advisories can prompt timely harvesting or connect farmers to nearby collectors, reducing labor bottlenecks that otherwise cause crops to rot in the field (as noted by WFP). Mobile apps also improve resource use to indirectly reduce waste. For example, precision-agriculture apps guide water and fertilizer applications, “leading to increased efficiency and reduced waste” of inputs. Fewer input losses and healthier crops mean a higher harvest share. ICT also contributes to circular-economy strategies: blockchain tracking enables surplus redistribution and better matching of local supply and demand (though detailed studies of this in smallholder contexts are still emerging). In developing contexts, the literature remains sparse on end-to-end waste-ICT solutions, but early pilots are promising. Some projects use drones for aerial crop monitoring to decide optimal harvest timing. Others use SMS alerts to arrange quick collection of produce after harvest. Taken together, these technologies increase food visibility (traceability and status) and coordination among actors, which can slash waste. Ganeshkumar et al. suggest that improving SCM infrastructure (financing, tech access) is key to reducing losses. In practice, integrating digital tools into cold chains and rural warehouses is an active research frontier, especially for high-value perishables in India and Africa.

III. METHODOLOGY

The reviewed studies use diverse methods. Econometric analyses are common: for instance, Nwangwu et al. (2024) collected cross-sectional survey data from 360 Nigerian farmers and employed a double-hurdle model (and propensity-score matching) to quantify how mobile ownership affects market participation. Many economics papers similarly use household surveys or field experiments to link ICT usage with outcomes (prices obtained, volumes sold, etc.). Case studies and pilot interventions also feature prominently. The mobile CHAPONA work followed a Design Science Research (DSR) approach: identifying farmer information needs, then iteratively prototyping and evaluating a smartphone app. Mixed-method field trials (combining usability tests, usage data, and interviews) showed that farmers used the app effectively for information exchange. Literature reviews provide broader perspectives: Galera Zarco (2025) conducted a systematic literature review of 111 papers on digital food waste solutions, mapping which technologies address specific loss points. This multiple-technology approach guides supply-chain managers on best practices. In the engineering domain, studies frequently use mixed-methods or case-study frameworks (e.g. the 2025 Sustainability article used data analytics and interviews to evaluate an IoT/AI waste management system). Qualitative methods appear in some innovation studies: needs assessments and participatory design ensure tech is user centric. For example, Misaki’s thesis employed user-centered design workshops with farmers and advisory agents to shape the mobile CHAPONA app. On the other end, some papers survey technology adoption barriers through interviews or focus groups (not covered in our source papers but common in ICT4D research). Overall, methodologies range from statistical modeling of survey data to prototyping of digital tools, illustrating that the field is both empirical (testing existing technology impacts) and constructive (building new applications). A recurring observation is the need to combine quantitative rigor with local context understanding; successful projects often involve local stakeholder collaboration in design.

IV. RESEARCH GAPS IDENTIFIED

Despite growing interest, the literature still has notable gaps. One major gap is integration across themes: most studies focus on one link (e.g. mobile extension or e-market); few evaluate entire food-flow models end-to-end. There is a need for holistic case studies that trace how an ICT intervention affects farm operations, market outcomes, and waste simultaneously. Similarly, farmer income impacts are often inferred rather than directly measured. Many studies show improved knowledge or market participation (e.g. Nwangwu’s statistical model), but rigorous impact evaluations linking ICT to net income gains (after accounting for costs) are rare. Another gap is in food-loss measurement. Quantifying reductions in waste due to digital tools is challenging, and so far evidence is anecdotal or limited to

simulations. More field trials are needed, especially in rural cold chains. Likewise, scalability and adoption factors need deeper study: while models like e NAM scale widely, many mobile apps fail to reach beyond pilot regions. Research is needed on how to sustain and finance ICT systems (e.g. platform fees, public-private partnerships), echoing Ganeshkumar’s point on financing and accessibility. Contextual gaps exist too. Many case studies are from select countries (India, Bangladesh, a few in Africa); regions like Sub-Saharan Africa have fewer documented supply-chain ICT models than India. Cross-country comparative studies could reveal which models are most transferable. Finally, there is a data gap on gender and equity: few studies disaggregate how women farmers benefit from (or are excluded by) ICT solutions, despite known disparities in smartphone ownership.

V. COMPARATIVE MODELS

Table 1: Examples of ICT-driven agricultural supply chain models and studies, highlighting regions, technologies, and main impacts (selected from cited literature). For instance, digital platforms like e NAM (India) and mobile apps (Nigeria, Bangladesh) improve price transparency and market integration, while technology-enabled SCM (India) addresses waste

TABLE I EXAMPLES OF ICT-DRIVEN AGRICULTURAL SUPPLY CHAIN MODELS

Study / Model	Region	Technology/Methodology	Focus /Outcomes
Nwangwu et al. (2024)	Nigeria	Mobile phones, radios; econometric modeling (double-hurdle model, propensity score matching)	Farmers with access to mobile phones were significantly more likely to participate in staple crop markets. ICT tools improved access to price information and agronomic knowledge, supporting informed marketing decisions.
Kamal and Bablu (2022)	Bangladesh	Smartphone applications for market information, weather updates, e-extension services, and mobile finance	Reviewed multiple mobile applications providing real-time price and weather data, direct farmer-buyer linkages, and digital financial services. These platforms reduce dependence on middlemen and improve farmer profitability.
Mittal and Mehar (2012)	India	Mobile phone-based agricultural information services	Demonstrated that rapid mobile penetration has helped bridge information gaps in Indian agriculture by improving farmer knowledge of inputs and production practices, partially compensating for weak traditional extension systems.
Mudda et al. (2017)	India	Supply-chain digitization and ICT-enabled logistics	Highlighted the role of ICT in addressing post harvest losses by improving market connectivity, traceability, and coordination across agricultural supply chain actors, thereby enhancing farmer incomes.
e NAM (2016–present)	India	Pan-India electronic agricultural market place (web and mobile platform)	Connects over 1,000 regulated markets through a unified digital trading platform. Integrated quality assaying and electronic weighing systems enable transparent price discovery and wider market access for farmers.
Mobile CHAPONA (Misaki, 2021)	Tanzania	Design Science Research (DSR)-based mobile application for information exchange	A participatory-designed smartphone platform enabling farmers and extension agents to share agricultural information. Pilot deployment showed improved information flow and reduced agricultural knowledge gaps among stakeholders.

VI. CONCLUSION

The reviewed literature converges on a hopeful message: digital technologies can significantly improve visibility and efficiency in agricultural supply chains. Mobile phones and apps bring market price information and extension advice directly to farmers, reducing information asymmetry. Digital marketplaces and e-platforms connect farmers to a broader array of buyers, cutting out exploitative middlemen. Sensor networks, data analytics, and smart logistics promise to cut spoilage and waste at multiple stages. The Figure illustrates the potential intervention points along a

simplified food chain. Case studies from India, Bangladesh, Nigeria, and East Africa show tangible benefits: farmers using ICT report better yields, higher prices, and reduced losses. For example, a farmer using a price app can time sales to markets (perhaps via e NAM) and use mobile banking to get instant payment— a win-win. Likewise, a network of IoT-equipped storages can alert communities to impending spoilage, enabling timely redistribution or processing. Nevertheless, realizing this potential broadly requires addressing remaining challenges: ensuring consistent internet access in remote areas, providing farmer training, and designing user-friendly systems (older farmers may need specialized interfaces). Policies that subsidize rural broadband, integrate ICT into extension services, and invest in cold-chain infrastructure will amplify tech gains. In conclusion, ICT-driven agricultural supply chain models show great promise for enhancing food flow and farmer livelihoods. The reviewed research demonstrates multiple pathways by which technology augments visibility, reduces waste, and increases farmer share of the food dollar. Future work should strive for comprehensive models and robust field validation, particularly in resource-poor settings. Bridging the identified gaps will move us closer to resilient, food-secure rural economies enabled by smart supply chains.

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