

Building Sustainable Food Systems Using Artificial Intelligence

Innovation in Agricultural Value Chains





The benefits of data-driven solutions have been well-recognized across nearly all industries worldwide. With the rapid advancements in the availability, affordability, and accessibility of AI, we are now witnessing a new wave of digital transformation at an unprecedented scale. AI has the potential to significantly enhance the efficiency of agricultural value chains, enabling providers to become more agile, streamlined, and effective in better serving communities.

AI's transformative capabilities extend beyond operational efficiency. It can play a critical role in shifting agriculture from being a major contributor to over a quarter of global greenhouse gas emissions to becoming a net carbon sink. Advanced AI solutions can aid in sequestering more than a third of atmospheric carbon, enhancing yields, and create new revenue streams for farmers through carbon credit markets.

This potential is especially crucial for frontier markets, which, unburdened by legacy infrastructure, have a unique opportunity to embrace AI swiftly. Just as mobile money accelerated financial inclusion in countries like Kenya and India's IT revolution set a global benchmark, proactive investment and adoption by governments, entrepreneurs, and investors could propel these markets to lead in the AI era.

Accendo is at the forefront of this shift, collaborating with partners to build AI Labs and support the incubation of AI-focused startups that serve agricultural value chains. Our efforts are aimed at catalyzing digital transformation across various domains, including financial services, insurance, healthcare, carbon markets, and logistics.

While the field is complex and often surrounded by hype, this paper zeroes in on practical implications. Although the context touches on the global food system, the primary focus is to explore how the digital transformation of agricultural value chains, powered by AI, can foster sustainability and resilience for smallholder farmers, ultimately benefiting us all.

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Efficient food systems are at the root of survival.

The global food production and distribution system faces unprecedented challenges due to rapid population growth, climate change, and finite natural resources. Global food demand is estimated to [increase](#) by more than 50% to feed a projected global population of [9.7 billion people](#) by 2050. Agricultural value chains need to increase their output while [adapting to climate change](#) – diversifying crops, improving irrigation systems, changing planting patterns, and focusing on soil health. Land and water are finite resources, critical to agriculture, and increasingly [under pressure](#) owing to population and economic growth. Compounding these issues further, up to a [fifth of all food produced worldwide is lost or wasted](#), translating to nearly \$1 trillion in economic losses annually.

Simply “growing more” will be insufficient, since current practices rely heavily on intensive agricultural techniques that deplete soil health, [pollute water sources](#), and drive [biodiversity loss](#). Our current methods are [unsustainable](#).

Emerging markets, and frontier markets in particular, feed and fuel [most of the world](#). Most farmers in these markets are smallholder farmers. There are an estimated [600 million smallholder farmers](#) managing over 90% of the world's [570 million farms](#), meeting over 30% of global food demand, for close to 2 billion people. These farmers often lack access to critical resources such as modern farming techniques, affordable financing, and access to reliable markets. Additionally, they are disproportionately impacted by climate change, which threatens to disrupt crop cycles and yields, thus exacerbating food insecurity. As a result, these farmers are on a downward spiral from an already bad situation of widespread [poverty and malnutrition](#). Without significant changes, frontier markets will not be able to sustainably feed their own rapidly growing populations and the rest of the world.

Addressing these inefficiencies isn't just a matter of optimizing supply chains or improving yields; it's about creating a food system that is sustainable, resilient, and equitable for future generations and our planet. Transforming the global food system could realize benefits of up to [\\$10 trillion per year](#).

Artificial Intelligence (AI) presents a pivotal opportunity to drive the transformation of food systems. Leveraging AI to enhance predictive analytics, optimize resource allocation, and improve decision-making can empower farmers, streamline supply chains, and reduce waste.

However, these innovations must be accessible, adaptable, and context-specific to address the unique challenges faced by emerging and frontier markets. As food insecurity grows and the impact of climate change becomes increasingly severe, it is imperative that we act swiftly to create food systems that not only meet the needs of a burgeoning global population but do so in a way that is sustainable, equitable, and resilient.

The scope of this paper is not to address the entire food system, but to explore how digital transformation of agricultural value chains, leveraging AI, can support the sustainability and survival of smallholder farmers and, to a great extent, the rest of us.

The agriculture value chain – from seed to plate.

As shown in Figure 1, the agricultural value chain is a series of steps that take crops from initial inputs through to final distribution and eventual consumption, with essential supporting tasks.

The chain begins with the “sowing” phase which needs key inputs, the foundational resources required for agriculture. These include land rights, which establish ownership and control; seeds, fertilizers, pesticides, and herbicides, which are vital for crop growth; labor and power, necessary for operational activities; and finance, enabling farmers to access needed resources. Access to

reliable and environment-friendly inputs determines the productivity and quality of subsequent stages, setting the tone for the entire value chain.

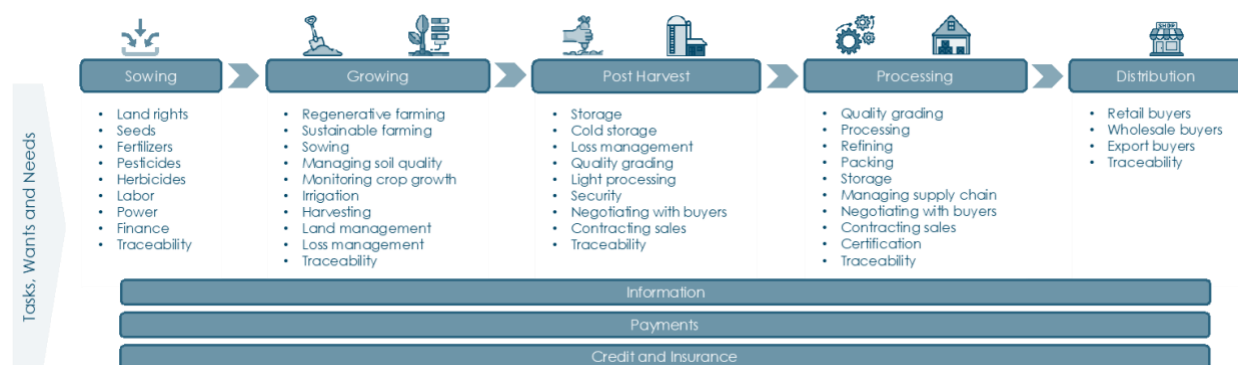


Figure 1: The multiples stages and components of agricultural value chains

In the “Growing” stage, activities revolve around converting inputs into crop yield. Key activities involve sowing, managing soil quality, and monitoring crop growth, supported by practices like irrigation, harvesting, and effective land management. By focusing on sustainable practices, tasks in this stage can help maintain soil health, enhance long-term agricultural productivity and minimizing environmental impact.

During the “post-harvest” stage, tasks such as pre-processing, logistics, storage, and preserving produce, are essential to maintain quality. An increasingly crucial component from here on in the chain is traceability, especially in light of the [EUDR regulation](#), which tracks the origin and quality of inputs to ensure sustainability, safety of people and produce, and protection of forests.

In the “Processing” stage, raw agricultural products are transformed into consumable or market-ready forms. Key tasks include quality grading, processing, refining, packing, and storage. Certification and traceability are critical in this stage to meet regulatory standards and build trust with consumers, especially in international markets. Processing adds value to raw products, often increasing their market value and shelf life, making them more accessible to a broader range of buyers.

The final stage, “Distribution”, focuses on delivering the processed goods to retail, wholesale, and export buyers. Distribution channels determine how efficiently products reach markets and, ultimately, consumers, impacting the accessibility and affordability of food, especially in underserved regions.

Beneath these stages lie three supporting layers. [Information](#) at the time of need, at point of use, enhance decision-making and transparency across all stages. [Secure and efficient payments](#) between farmers, suppliers, processors, and buyers ensure liquidity and stability of the chain. Finally, [Credit and Insurance](#) are vital for risk management and financial access, offering financial security needed to invest in productivity-enhancing technologies and sustainable practices.

In summary, the agricultural value chain is complex, performed by various actors (businesses, people and communities) that have their own needs and requirements. Optimizing this chain—especially in frontier markets—is key to boosting productivity, minimizing losses, and ensuring that food reaches consumers sustainably and affordably.

What is AI?

AI is the field of study, and application of tools, that simulate human intelligence processes in computer systems. In general, “training” AI systems works by ingesting large amounts of data and analyzing it for correlations and patterns, to make *predictions* about future states or *generate* entirely new data.

There are several subsets within the field of AI, based on their input mechanisms, processing approach and output types. Figure 2 showcases the most relevant to our context.

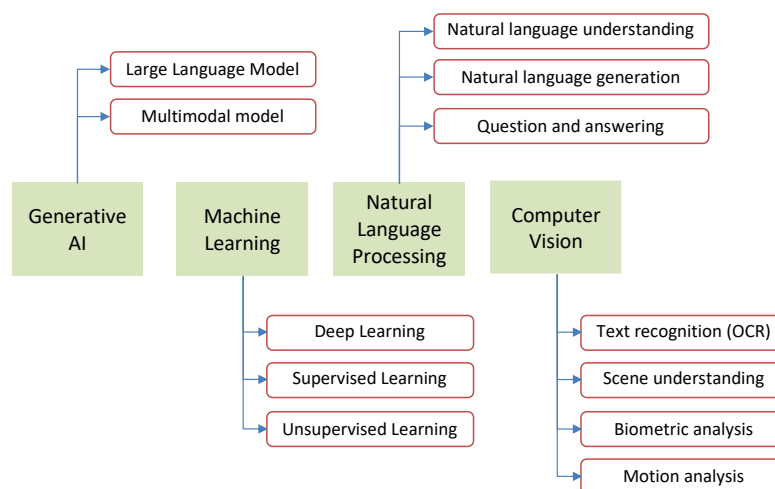


Figure 2: There are several types of AI and some more relevant to ag value chains than others

Machine learning (ML) is a well-entrenched subset of AI that enables computers to autonomously learn without being explicitly programmed. ML models are created from algorithms, which undergo a training process using either labeled, unlabeled, or mixed data. Enterprises will find this technology useful for credit approvals, fraud detection, process improvements, increasing channel usage, among other things.

Natural language processing (NLP) deals with the ability of computer systems to understand and generate human language – spoken or written. NLP algorithms are used to analyze text, comprehend, converse with users and perform tasks like language translation, sentiment analysis, and question answering. This is useful for creating chatbots over WhatsApp for example that are voice-based to overcome literacy challenges.

Computer Vision (CV) empowers computers to 'see' and comprehend the visual world, analyzing images and videos like humans do. CV algorithms analyze images and videos so that this can be used for tasks like Know-your-Customer (KYC) management, biometric/face recognition, and document management.

Generative AI creates new and unique outputs, such as images, texts, music, or even computer code by learning from data patterns. Gen AI is unlike other forms of AI that are usually designed to perform specific tasks. Gen AI can be leveraged for tasks such as training staff, customer education, innovating products, and process improvement recommendations.

AI tools have been around since the 1980s. Early iterations of the now familiar AI applications were built on traditional statistical analysis models, based on the work of Sir Ronald Fisher between 1925 and 1935. Even though AI's rapid progress was evident in the technology community, OpenAI's big splash release of ChatGPT in November 2022 brought AI to the forefront and caught the imagination of the public globally. And this trend is here to stay, as

evidenced by the fact that AI-based startups received over 25% of investments in 2023 and Goldman Sachs [projects](#) that private investments in AI will grow from \$92 billion in 2022 to over \$200 billion in 2025.

AI can accelerate the digital transformation of the agriculture sector.

The agriculture sector has been adopting, albeit mostly in developed markets, new digital technologies such as precision farming, internet of things, remote sensing, unmanned aerial vehicles, data-driven applications, digital twins, robotics and many more.

AI, specifically, has emerged as a transformative tool in enhancing the efficiency and resilience of agricultural value chains, offering unprecedented possibilities for addressing long-standing challenges across production, post-harvest management, processing, and distribution. At every stage, AI can streamline operations, reduce waste, and provide actionable insights that enable stakeholders—from smallholder farmers to large agribusinesses—to make data-driven decisions, ultimately boosting productivity and profitability.

Given the vast array of possibilities, it can be confusing to navigate the AI universe. A framework that actors in the agricultural value chains can use to determine the key areas of focus is three layered: **AI for business growth**, **AI for operational efficiency**, and **AI for product innovation**. Figure 3 showcases some examples of how AI might support players in the agricultural value chain by helping them become more efficient.

To support business growth, AI can help with...	To increase operational efficiency, AI can help with...	To support product innovation, AI can help with...
Analyzing demand patterns and market trends, helping smallholder farms identify new markets and opportunities to sell produce, enabling better market access and expanding reach.	Analyzing satellite imagery and IoT sensor data to monitor soil health, crop growth, and environmental conditions, enabling timely interventions and reducing crop loss.	Analyzing climate data and identify crop varieties that are more resilient to drought, floods, or pests, helping farmers adapt to changing environmental conditions.
Building segmentation models that categorize farmers and suppliers based on productivity, soil conditions, or crop types, allowing tailored services and interventions that increase yield.	Optimizing the use of water, fertilizers, and pesticides by analyzing crop requirements and weather patterns, improving resource efficiency and reducing costs.	Providing customized recommendations based on individual farmer conditions—such as soil quality, crop type, and local weather—making advisory services more relevant and effective.
Recommending additional services like financing options, crop insurance, or advisory services, enabling farmers and suppliers to improve income and reduce risk.	Improving logistics by optimizing transportation routes, storage facilities, and inventory levels, minimizing post-harvest losses and reducing costs.	Powering platforms that directly connect farmers with buyers, enabling transparent pricing, reducing reliance on intermediaries, and increasing farmer income.
Enhancing farmer loyalty and engagement through personalized loyalty schemes or rewards for sustainable practices, promoting long-term relationships and stable supply chains.	Predicting equipment breakdowns and suggest maintenance schedules, reducing downtime for machinery and improving productivity, especially for processing equipment.	Tracking produce from farm to market, ensuring quality, safety, and origin authenticity, meeting consumer demand for transparency and enabling compliance with regulatory standards.

Figure 3: Examples of how AI might increase the efficiency of agricultural value chains

In summary, AI has the potential to drive significant transformation across agricultural value chains. By fostering business growth, enhancing operational efficiency, and spurring product innovation, AI can create a more resilient, sustainable, and productive agricultural ecosystem that benefits farmers, businesses and consumers alike. This transformation is particularly impactful in emerging markets, where the agricultural sector is key to economic development and food security.

AI can increase the efficiency of smallholder farmers.

AI is revolutionizing agriculture by providing smallholder farmers with tools that enhance productivity, sustainability, and resilience. Smallholders, who produce 30% of the world's food, often face challenges such as limited access to resources, unpredictable weather, and pests and diseases that threaten crop yields. Tailored solutions, as shown in Figure 4, can offer deep benefits by addressing specific needs and challenges that farmers face.



Figure 4: Smallholder farmers can benefit from AI tools in many ways

1. **Predictive Analytics** uses historical and real-time data to forecast agricultural outcomes, assisting smallholder farmers in making crucial decisions on planting schedules, harvesting times, and pricing strategies. By analyzing weather patterns, soil conditions, and crop growth data, AI-powered predictive models can help farmers maximize yields while minimizing costs. This allows them to plan for favorable market conditions and avoid potential losses due to climate or market fluctuations.
2. **Pest and Disease Management** is one of the most challenging aspects of farming, particularly for smallholders with limited access to advanced resources. AI-driven image recognition and diagnostic tools can help farmers identify pests and diseases accurately and early. By leveraging data from similar cases, systems can provide tailored recommendations for pest control and disease management, reducing the need for broad-spectrum pesticides, which can be costly and environmentally damaging. This targeted approach contributes to sustainable farming practices.
3. **Soil Analysis** tools can provide farmers with insights into soil composition, nutrient levels, and moisture content. Based on these insights, AI systems can suggest optimal fertilizer application rates, irrigation schedules, and crop rotation practices. This enables farmers to maintain or improve soil health over time, which is critical for sustained productivity. By using

resources more efficiently, smallholder farmers can lower input costs and increase crop yields, ultimately improving their livelihoods.

4. **Crop Monitoring** allows farmers to stay informed about the health of their crops. AI-powered sensors and drones can monitor crop growth, detect stress conditions, and identify issues such as nutrient deficiencies, water stress, or disease outbreaks. Early detection of these issues enables farmers to intervene before problems become widespread, thereby minimizing losses. Through crop monitoring, farmers can maintain healthier crops and achieve higher productivity with more precise management.
5. **Market Access** is often a significant barrier for smallholder farmers, who rely heavily on layers of middlemen that reduce their profit margins. AI-driven platforms can connect farmers directly to buyers and consumers, providing real-time market information on prices, demand, and competition. These platforms also enable digital marketplaces where farmers can showcase their products, expanding their reach and improving profitability.
6. **Livestock Management** can be enhanced by monitoring animal health, productivity, and behavior. Wearable sensors and AI algorithms can detect early signs of disease, monitor feeding habits, and optimize breeding cycles. This early detection and intervention reduce mortality rates, improve herd health, and increase productivity. Optimizing feeding practices also lowers costs and maximizes growth rates, leading to better economic outcomes for farmers with livestock operations.
7. **Climate Change Adaptation** is critical to agricultural stability, particularly for smallholder farmers who lack resources to adapt. AI can help recommend efficient irrigation practices, and suggesting conservation measures based on climate forecasts and soil data. These tools enable farmers to adopt practices that mitigate the effects of unpredictable weather patterns, such as droughts or floods, helping them to maintain stable production and build resilience against climate change impacts.

These AI applications collectively equip smallholder farmers with the tools needed to overcome traditional farming challenges, adapt to environmental changes, and improve their economic resilience. Through these innovations, AI supports a more sustainable, regenerative, and inclusive agricultural sector, crucial for meeting the food needs of a growing global population.

AI can accelerate the financial inclusion in the agriculture sector.

AI has the potential to drive financial inclusion across the agriculture sector by tailoring financial products and services to meet the unique needs of each actor in the agricultural value chain. Figure 5 summarizes how AI can support financial inclusion for each key actor in agricultural value chains.

Smallholder
Farmers

- **Credit Scoring and Lending:** AI-powered algorithms can analyze alternative data sources, such as transaction histories, farm productivity, and soil quality, to create more accurate credit scores for smallholder farmers who lack formal financial histories. This enables financial institutions to offer microloans and customized financing to farmers who are typically excluded from traditional credit systems.

	• Risk Management and Insurance: AI models can analyze climate, crop, and yield data to assess risks and design affordable insurance products tailored to smallholder farmers. For instance, AI can support weather-indexed insurance, which automatically compensates farmers in the event of adverse weather conditions, making it easier for them to recover from losses. • Financial Literacy: AI-powered chatbots can deliver personalized financial literacy education to farmers in local languages. These tools guide farmers on budgeting, loan management, and savings, improving their financial management skills.
Input Suppliers	• Demand Forecasting: AI can help input suppliers (providers of seeds, fertilizers, and pesticides etc.) predict demand more accurately by analyzing crop data, weather patterns, and market trends. This helps suppliers better manage their inventory thereby optimizing their working capital. • Flexible Payment Solutions: AI-enabled credit scoring can support the provision of credit for input suppliers, allowing them to offer flexible plans to farmers. For example, suppliers might extend credit with repayment linked to the harvest cycle, ensuring that farmers have access to inputs even when cash flow is tight.
Agribusinesses and Cooperatives	• Credit Underwriting: For cooperatives and agribusinesses, AI-driven credit underwriting models can use both historical and real-time operational data to assess creditworthiness and determine optimal loan terms. By factoring in variables like yield records, cooperative productivity, and cash flow, AI enables financial institutions to provide more suitable financing options. • Supply Chain Financing: AI can facilitate supply chain financing by analyzing transaction data between farmers, cooperatives, and buyers, thereby reducing the perceived risk for lenders. This enables agribusinesses and cooperatives to access working capital that can be used to purchase crops from farmers at fair prices and pay them promptly, enhancing cash flow throughout the chain.
Processors and Exporters	• Invoice Financing: AI systems can automate invoice processing, allowing processors and exporters to receive financing against unpaid invoices more quickly. This enables these businesses to maintain liquidity and continue operations while waiting for payment from downstream buyers. • Fraud Detection and Traceability: AI algorithms can analyze transaction patterns to identify anomalies or potential fraud, especially in high-volume operations like processing and export. This builds trust in the financing ecosystem, which is essential for processors and exporters to access affordable financing options.
Supporting Layer: Digital Payment Platforms	• Payment Solutions: AI-driven payment solutions can facilitate digital transactions across rural markets, enabling more farmers and suppliers to sell their products directly to retailers or consumers. By reducing reliance on cash, these payment solutions also reduce transaction costs and improve security.

- **Mobile Banking and Wallets:** AI enables mobile banking platforms to adapt to the needs of farmers and other actors in the agriculture value chain. By using transaction data, these platforms can offer targeted microloans, savings plans, and insurance products, all of which support financial inclusion.
- **Agent Network Optimization:** AI can help optimize agent networks by identifying areas where banking agents are needed most, improving access to financial services in remote areas, ensuring that more value chain actors can participate in digital financial transactions.

Figure 5: Smallholder farmers can benefit from AI tools in many ways

AI can accelerate financial inclusion in agriculture by breaking down traditional barriers to access. By customizing credit products, automating risk assessment, and improving cash flow across the agricultural value chain, AI can make financial services more accessible, affordable, and relevant for each actor. This ultimately contributes to a more resilient, inclusive agricultural sector that can thrive even in the face of economic and environmental challenges.

Reliable data collection is a major barrier to implementing AI

Implementing AI in agricultural value chains requires field data collection and seamless integration across diverse actors—each with varying technological capabilities. While data is essential for AI to provide insights on crop yields, pest management, and supply chain optimization, gathering and integrating data across large enterprises, cooperatives, and smallholder farmers is challenging.

For AI systems to deliver actionable insights, data must be gathered from multiple points along the value chain. Field-level data, such as soil moisture, crop health, pest incidence, and climate conditions, is essential for AI models that guide farmers in real-time. Financial and transactional data from cooperatives, agribusinesses, and input suppliers further enhances AI's accuracy in generating credit scores, demand forecasts, and inventory management insights. However, data consistency across actors is critical for these insights to be actionable.

Establishing standardized data collection protocols and accessible digital solutions could help bridge these gaps, but implementing these consistently requires substantial investment in training and infrastructure.

Data integration across a diverse set of actors presents further challenges. While larger agribusinesses may use sophisticated systems, smaller players often lack compatible digital records. APIs can enable data exchange between systems, but interoperability is limited when many actors lack digital infrastructure. Establishing standardized data formats and protocols is essential to ensure smooth data flow, but achieving consistency across systems and varying levels of digital literacy requires considerable coordination.

For AI to be widely beneficial, solutions must be adaptable to both high- and low-tech environments, enabling all actors in the chain to participate. Scalable AI tools and mobile applications with offline functionality can make insights accessible to smallholders without heavy investments. Partnerships with governments, agribusinesses, and tech providers could further subsidize digital access for smaller players, promoting more equitable participation.

To harness AI's full potential in agriculture, overcoming data collection and integration challenges is essential. By addressing these barriers through inclusive design, improved connectivity solutions, and standardized data protocols, AI can drive productivity and resilience across the agricultural value chain. This approach supports a unified digital ecosystem where all

actors—from smallholder farmers to large enterprises—can benefit, creating a more efficient and sustainable agricultural landscape.

To be managed, the risks must be well understood.

Implementing AI solutions in agricultural value chains holds significant potential, but it also introduces several risks that must be carefully managed to ensure success and sustainability. Figure 6 showcases some of the primary risks and strategies for managing them.

Type	Risk	Mitigation
Data privacy and security risks	AI systems rely on large datasets, including sensitive information about farmers, soil health, crop yields, financial transactions, and land ownership. The collection and storage of such data can expose farmers and agribusinesses to privacy breaches, unauthorized access, or misuse of personal and financial information	Implement strong data privacy policies and cybersecurity measures, such as end-to-end encryption, secure data storage, and multi-factor authentication. Ensure compliance with local and international data privacy regulations and educate farmers and stakeholders about data rights and security practices.
Bias and Fairness in AI models	AI algorithms may inherit biases from training data, leading to unfair outcomes for certain groups, particularly marginalized or resource-poor farmers. This can result in discriminatory practices, such as denying loans to certain groups based on biased data or offering less favorable terms.	Use diverse, high-quality data to train AI models and continuously monitor for biases. Engage local stakeholders to validate the accuracy and fairness of AI models and conduct regular audits to ensure equitable outcomes. Transparency in AI decision-making processes and accountability mechanisms are also essential.
Digital literacy and accessibility	Many smallholder farmers and rural stakeholders may lack the digital literacy needed to use AI-driven tools effectively. This digital divide can limit the adoption and impact of AI solutions, especially in low-income and rural areas.	Develop user-friendly AI applications that accommodate low literacy and limited digital skills. Provide training and capacity-building initiatives tailored to farmers' needs, using local languages and culturally relevant materials. Partner with local cooperatives or NGOs to bridge the digital literacy gap.
Infrastructure and Connectivity Limitations	AI applications often require reliable internet connectivity and digital infrastructure, which may be lacking in rural and remote areas. This can limit the deployment and functionality of AI solutions, making it challenging to collect real-time data or provide timely recommendations.	Design AI solutions that function offline or with minimal connectivity. Use mobile-friendly platforms and leverage low-bandwidth technologies, such as edge computing, which can process data locally on devices instead of relying on cloud infrastructure. Explore partnerships with telecommunications companies to improve rural connectivity.
Economic Sustainability and Cost	High initial costs for implementing AI technology, including the acquisition of sensors, software, and training, may be prohibitive for smallholder farmers and other value chain actors. If not economically viable, AI solutions may lead to dependency without providing long-term value.	Offer flexible financing options, such as micro-loans or pay-per-use models, to make AI solutions more affordable. Collaborate with government agencies and development organizations to subsidize costs for resource-poor farmers. Focus on building cost-effective, scalable solutions to ensure long-term economic sustainability.

Quality and Reliability of Data	AI models depend on accurate and high-quality data. In agriculture, data inaccuracies can result from inconsistent data collection, variability in farming practices, or environmental factors. Poor data quality can reduce the accuracy of AI predictions and lead to incorrect recommendations.	Establish standardized data collection practices, train local partners in data quality management, and use sensor networks to automate and validate data collection. Regularly update AI models to adapt to changing environmental and market conditions, ensuring they remain relevant and accurate.
Dependency on Technology and Reduced Local Knowledge	Over-reliance on AI solutions can erode traditional knowledge and farming practices that have sustained communities for generations. If AI recommendations conflict with local knowledge, it may lead to a loss of farmer autonomy and cultural disconnect.	Integrate AI with local knowledge and engage farmers in co-developing AI solutions that respect traditional practices. Encourage a hybrid approach that combines AI insights with farmer expertise to enhance decision-making while preserving local knowledge.

Figure 6: Key risks to consider when implementing AI tools

Successfully implementing AI in agricultural value chains requires careful risk management and a commitment to inclusivity, transparency, and sustainability. By addressing these risks, stakeholders can harness the power of AI to create more efficient, resilient, and equitable agricultural systems that support food security and economic development, particularly in emerging markets.

Sowing AI-driven innovation cultivates efficiency of agricultural value chains

The digital transformation of agricultural value chains, powered by AI, presents a profound opportunity to enhance the efficiency, resilience, and sustainability of food systems, particularly in emerging markets where smallholder farmers produce a substantial portion of the world's food. AI-powered solutions, from predictive analytics to crop monitoring and market access tools, are addressing the chronic inefficiencies in agricultural value chains, enabling smallholder farmers to achieve higher productivity, reduce losses, and access better markets. In a world grappling with climate change, population growth, and resource scarcity, the adoption of AI in agriculture is not just a matter of convenience but a necessity for ensuring food security and sustaining livelihoods.

Smallholder farmers, who operate on thin profit margins, are particularly vulnerable to yield fluctuations, market volatility, and climate unpredictability. Through predictive analytics, AI offers these farmers a powerful tool to anticipate challenges before they arise. By analyzing historical and real-time data on weather, soil health, and market trends, AI can help farmers make informed decisions about when and what to plant, how to manage resources, and when to harvest. This level of foresight allows farmers to optimize inputs like seeds, fertilizers, and water, reducing waste and improving yield consistency. Predictive analytics also extends to demand forecasting, enabling suppliers to manage inventory better and ensuring that farmers have timely access to inputs, thus enhancing overall productivity across the value chain.

AI-driven pest and disease management tools further contribute to food system efficiency by helping farmers detect and address threats early. Through image recognition and data analysis, AI can identify pests and diseases, recommending precise interventions that reduce the need for broad-spectrum pesticides. This targeted approach not only reduces costs for farmers but also promotes sustainable farming practices by minimizing chemical use and protecting local ecosystems. Similarly, AI-supported crop monitoring solutions, which use sensors and drones to

track crop health, allow farmers to detect issues like nutrient deficiencies or water stress in real-time, leading to timely and effective responses that safeguard yields.

Another critical aspect of AI in agriculture is its role in enhancing market access for smallholder farmers. Traditionally, these farmers have been at the mercy of intermediaries, who often dictate prices and absorb a significant portion of profits. AI-powered platforms, however, can connect farmers directly to buyers or even end consumers, empowering them with better market insights and enabling them to capture a fairer share of the value they create.

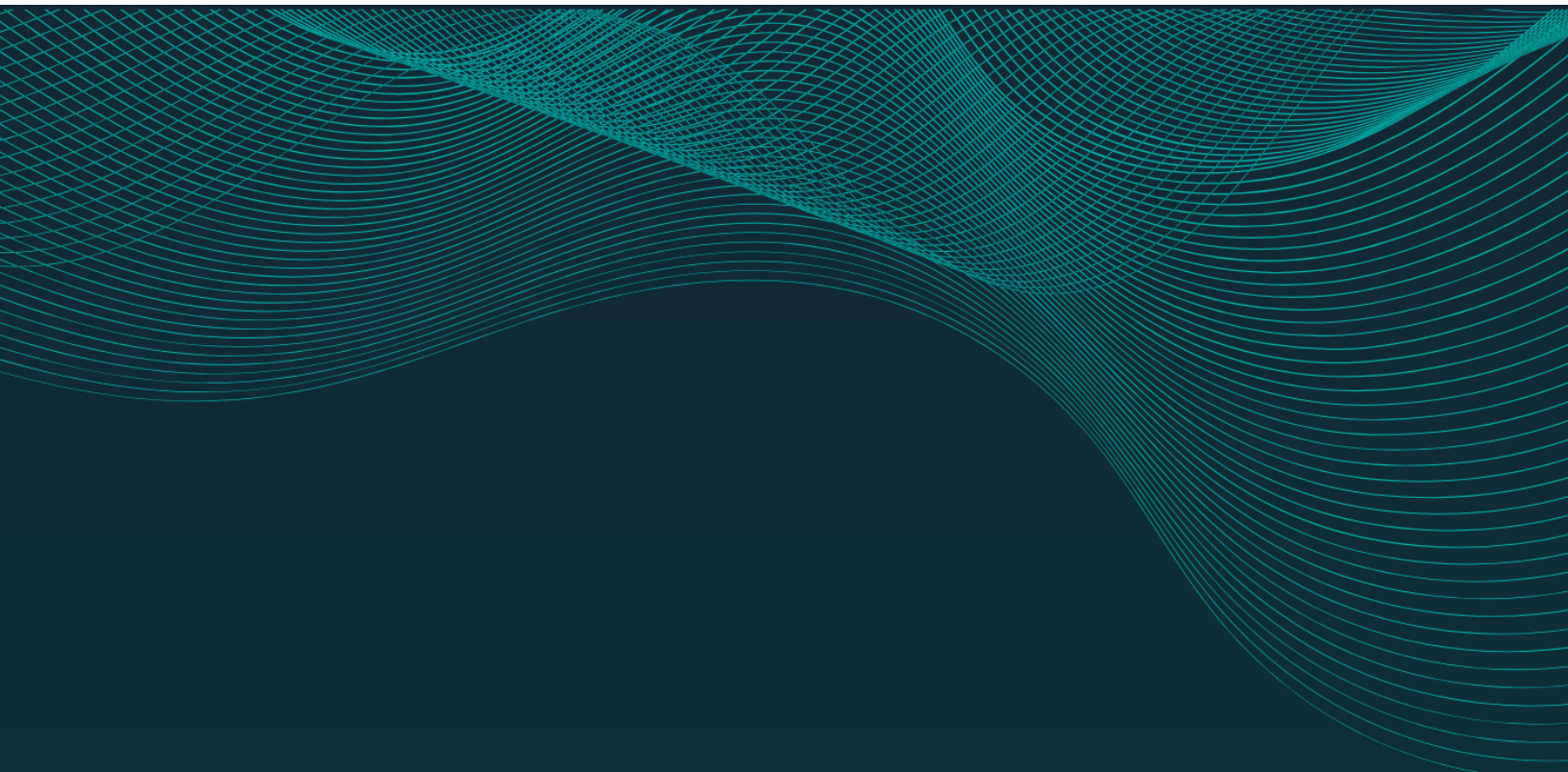
Moreover, AI is a game-changer in the realm of financial inclusion, which is critical for the sustainability of smallholder farming. AI algorithms can analyze alternative data—such as transaction histories, and farming practices—to create accurate credit scores for farmers who lack formal financial histories. This enables financial institutions to extend loans and insurance to farmers previously considered too high-risk, giving them the capital needed to invest in productivity-enhancing technologies and climate-resilient practices. With access to affordable finance, farmers can better manage cash flow, invest in their operations, and build resilience against shocks.

Beyond immediate financial gains, the AI-driven digital transformation of agricultural value chains supports the long-term sustainability of food systems. By optimizing resource use, reducing waste, and enhancing productivity, AI helps mitigate the environmental impacts of agriculture. Additionally, as AI solutions proliferate, they generate vast amounts of data that can inform better policy decisions and drive innovations in agricultural practices and technology. This data-driven approach has the potential to create a more sustainable and equitable agricultural landscape that supports smallholder farmers and secures food supplies for the global population.

Collectively, increases in efficiency can help make smallholder farmers resilient while adopting sustainable farming practices. Capacity building through AI-driven tools, coupled with insurances (guaranteed purchases, failure insurance, etc) will make it easier for farmers to adopt new methods and change their practices. This can result in a wider impact of economic growth and create excitement for younger people to take on work in the agricultural sector – increasing both political and economic stability of frontier and emerging markets.

While the potential of AI in transforming agricultural value chains is immense, it is essential to address associated risks to ensure that digital transformation is both equitable and sustainable. Key risks include data privacy, bias in AI models, digital literacy gaps, and infrastructure limitations in rural areas. By proactively managing these risks, AI-driven agricultural solutions can foster inclusive growth, supporting smallholder farmers while safeguarding their rights and well-being.

In conclusion, the integration of AI into agricultural value chains holds transformative potential for food systems worldwide, particularly in emerging and frontier markets. By empowering smallholder farmers with data-driven tools and market access, AI is creating a future where farming is more efficient, resilient, and profitable. For both farmers and consumers, the digital transformation of agriculture offers a sustainable path forward, one that will be essential for feeding a growing world and preserving the health of our planet.



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