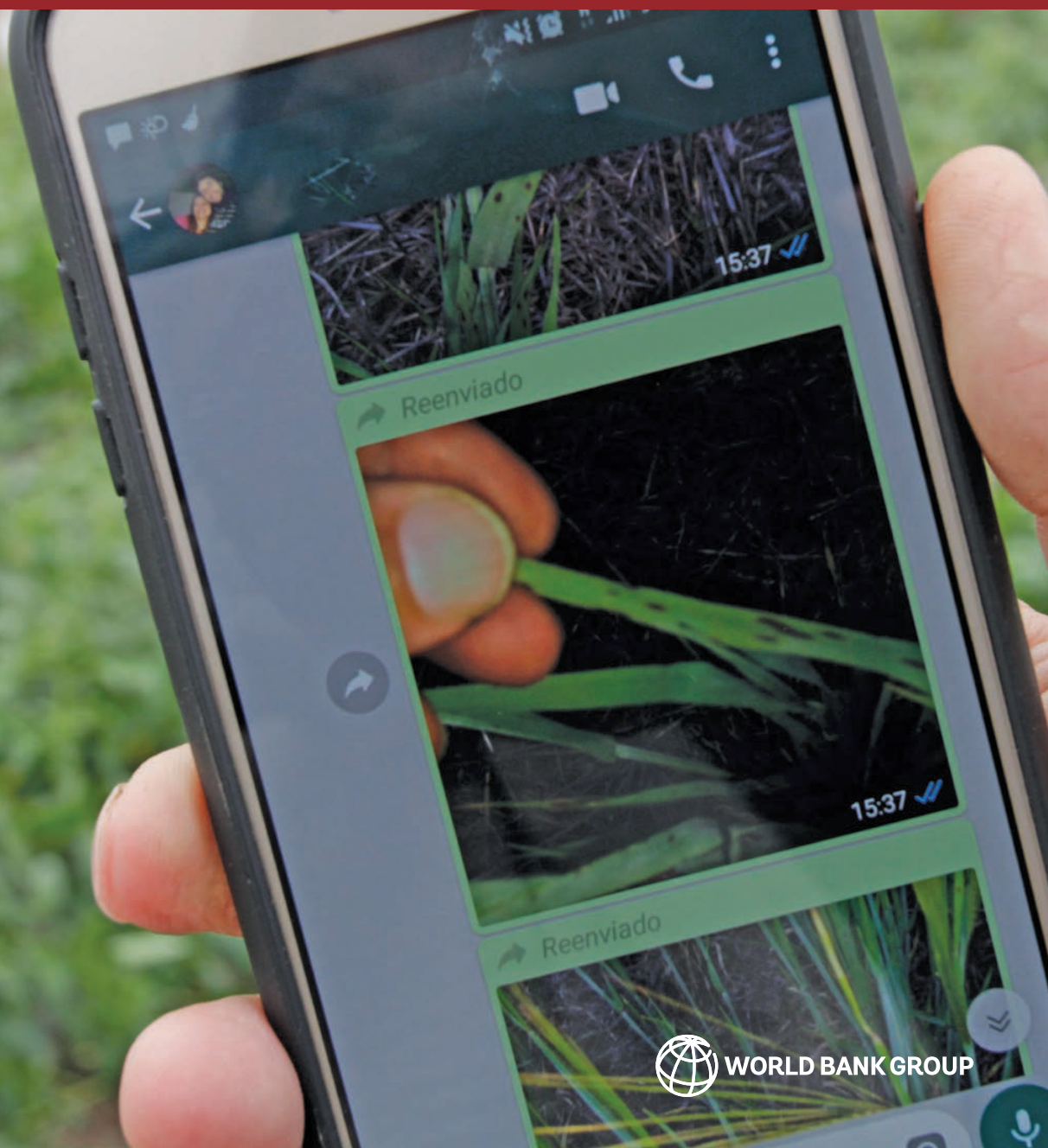


# FUTURE of FOOD

Harnessing Digital Technologies to  
Improve Food System Outcomes



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## FOREWORD

New and expanding information and communications technologies are bringing far-reaching change across the globe. Yet, these advances have recently coincided with a slowing of global poverty reduction, an increase in global hunger, and persistent natural resource degradation. How can we better harness the impact of digital technologies to tackle the world's pressing sustainable development challenges?

Improving the performance of the food system is a central part of reaching the Sustainable Development Goals. That's because the food system provides nourishment and supports livelihoods for most of the world's poor and better management of the system could strengthen the stewardship of the world's natural resources. Improvements in food system performance are associated with dramatic declines in poverty, hunger and natural resource degradation.

Over half of the world's population now has access to the internet and over 5 billion people subscribe to mobile phone services. Most people without access live in rural areas. Where there is coverage, adoption is often low due to factors such as cost, lack of knowledge and skills, and mistrust.

The World Bank Group is strongly committed to expanding digital opportunity for all, including for farmers and agribusiness. And we can do more to help countries use digital technologies to improve their food system outcomes in rural and urban areas.

This report looks at the opportunities from digital technologies, including better transparency of agricultural value chains, smarter farms, and improved public services. It also reviews some of the risks, including an over-concentration of service provider market power, poor data governance, and exclusion. It presents a set of potential entry points for public sector action to seize the opportunities that expanding rural network coverage can bring while fostering digital entrepreneurship and facilitating demand.

This report offers an opportunity to broaden the discussion on ways to more rapidly spread digital dividends and drive policy and investments that can deliver positive impacts for the food system, people and the environment.



Laura Tuck  
Vice President, Sustainable Development  
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## Key messages

- Digital technologies—tools that collect, store, analyze, and share information digitally, including mobile phones and the Internet—have significant potential to improve efficiency, equity, and environmental sustainability in the food system. They can: significantly reduce the costs of linking sellers and buyers; reduce inequalities in access to information, knowledge, technologies, and markets; help farmers make more precise decisions on resource management by providing, processing, and analyzing an increasing amount of data faster; and potentially reduce scale economies in agriculture, thereby making small-scale producers more competitive.
- A range of digital technologies in the food system are already leading to: better informed and engaged consumers and producers, smarter farms, and improved public services. These technologies range from simple off-line farmer advisory digital videos to complex systems requiring higher levels of mobile phone and Internet connectivity, such as distributed ledger technologies for value chain traceability and some forms of precision agriculture.
- Adoption of digital technologies varies significantly across countries, with lower current adoption rates in low-income countries. Increasing adoption of digital technologies in the food system will require addressing supply-side factors—such as rural network coverage and availability of digital applications—and demand-side factors, including skills and knowledge, trust, affordability, and complementary investments. Addressing these factors will require a range of public policy actions including increasing the space for private sector activity, improving the policy and regulatory environment, and using public investments to help crowd-in private sector investment.
- While digital technologies have significant potential they also pose several risks, including: an overconcentration of service provider market power; lack of data privacy; exclusion and potential job losses for some activities; and cybersecurity breaches. These risks cut across all segments of the economy, including the food system. Addressing these risks calls for public policy to: keep service provider entry barriers low; ensure good data governance; foster inclusion through targeted support to smallholder farmers, youth, women, and other vulnerable groups; and support skills development.
- While digital technologies offer significant opportunities to improve food system outcomes, they should not be viewed as a panacea. Other investments are needed to address the multiple constraints farmers face such as roads, energy, post-harvest storage, and logistics that can better link farmers to markets. Countries can also make policy improvements to increase incentives for farmers and agribusinesses to invest in farms and across agricultural value chains. These investments and policy improvements may in turn increase demand for digital technologies.





## Why harnessing digital technologies to improve food system outcomes matters

**The food system needs to play an active role in accelerating progress on ending poverty and hunger, contributing to growth and jobs, and better stewardship of the world's natural resources if the Sustainable Development Goals (SDGs) are to be achieved.**

- **Ending poverty:** The pace of global poverty reduction slowed to 0.6 percent between 2013 and 2015, well below the 25-year average decline of 1 percent per year.<sup>1</sup> This slowdown puts at risk achievement of the SDG target to end poverty by 2030. In 2015, 736 million people, 10 percent of the world's population, were living on less than US\$1.90 per day, of which 79 percent lived in rural areas and most relied on agriculture for their livelihoods.<sup>2</sup> While some of the poor will migrate to urban areas by 2030, most will not, and will continue to rely on income
- **Ending hunger, and improving nutrition and human capital:** Between 2015 and 2017, the number of people affected by hunger rose by 36.4 million, to 821 million.<sup>3</sup> In addition, more than 2 billion people are deficient in key vitamins and minerals necessary for growth, development, and disease prevention.<sup>4</sup> Energy and micronutrient deficiency contribute to the 151 million children under age five who are stunted and cannot grow to achieve their full potential. At the same time more than 2 billion adults are overweight and obese,<sup>5</sup> increasing the

risk of non-communicable diseases such as Type 2 diabetes, hypertension, heart attacks, and certain cancers. Furthermore, one person in 10 is impacted by contaminated food.<sup>6</sup>

- **Contributing to growth, providing more and better jobs, and boosting shared prosperity:** As countries become richer, per capita expenditures on food tend to rise, even as their share in household expenditures declines. With rising incomes, diets change and the share of income spent on cereals declines relative to other fresh, processed, and convenience foods. This change leads to increased food management and transformation beyond the farm, which have a multiplier effect in creating new enterprise growth opportunities and jobs in the broader food system. Farming (or agriculture) still employs more people than any other sector in many countries, accounting for an estimated 67 percent of total employment in low-income countries.<sup>7</sup> The food system also accounts for a large share of manufacturing and services jobs. For example, in Malawi and Tanzania, food and beverages account for more than 40 percent of total manufacturing employment.<sup>8</sup> Even in the European Union (EU), the food and beverage industry represents a larger share of employment than other manufacturing sectors.<sup>9</sup>
- **Better stewardship of the world's natural resources:** Global agricultural production practices are currently unsustainable. The annual cost of land degradation is about US\$300 billion per year,<sup>10</sup> about one-third of the world's largest aquifers are being depleted,<sup>11</sup> and agricultural

pollution is on the rise.<sup>12</sup> Under current practices, greenhouse gas (GHG) emissions from agriculture and land use change are projected to represent 70 percent of total allowable emissions from all economic sectors to limit global warming to 1.5°C by 2050.<sup>13</sup> If climate change goes unmitigated, the total days under drought conditions are projected to increase by more than 20 percent in some regions.<sup>14</sup> Further, food that is harvested but then lost or wasted occupies total arable land equal in size to China, consumes about 25 percent of all water used in agriculture each year, and accounts for about 8 percent of global GHG emissions.

## Characteristics of the food system make it ripe for expanded use of digital solutions

The food system has several characteristics that offer significant potential for digital solutions to have positive impacts:

- **Large and complex, with many actors:** The global food system is complex, involving many actors exchanging vast amounts of information. It comprises about 100,000 enterprises supplying inputs such as seeds, fertilizers, machinery, animal health services, crop and livestock insurance, finance, and livestock feed to 570 million farms around the world, many in remote areas. And millions of informal and formal enterprises move, process, and sell agricultural outputs to 7.5 billion consumers. Digital technologies have the potential to significantly



reduce the costs of linking these actors in the food system, more efficiently matching buyers and sellers; and helping to better target poor and vulnerable farmers with support services.

- **Large inefficiencies:** The food system's inefficiencies are reflected in its unsustainable use of land and water, and significant food loss and waste. Food production, as a biological process, requires many decision points that affect production efficiency, such as what and when to plant; and what, how much, when, and where to apply fertilizer and water optimally, which depend on other factors such as soil type, soil moisture, and weather forecasts. In this data-intensive process, farmer decision making on resource management can be improved by processing and analyzing more data faster, particularly considering the impact of climate change.
- **Asymmetric access** to technologies, knowledge, information, and markets lead to lack of equal opportunity, and contribute to poverty and hunger, inequality, and unsustainable use of natural resources. Digital technologies can potentially reduce inequalities in access to information, knowledge, technologies, and markets.

**Digital technologies have been spreading rapidly across various sectors and regions, driven by lower costs, better connectivity, and advanced analytics.** Network coverage and mobile phone use has increased significantly in recent years. As of 2017, there were 5 billion unique mobile subscribers (66 percent of the world's population), and 3.3 billion mobile Internet users (43 percent

of the world's population).<sup>15</sup> Sub-Saharan Africa was the only region with mobile subscriber and mobile Internet penetration rates significantly lower than the global aggregate, with rates of 44 percent and 21 percent, respectively.<sup>16</sup> While there has been a significant expansion of network coverage beyond urban areas, the vast majority of the 1.2 billion people worldwide not covered by a broadband-capable network live in rural areas.<sup>17</sup> Advances in analytics are transforming enormous amounts of digital data into useable form for decision makers. Over the past 10 years, agriculture has experienced remarkable growth in ag-tech<sup>18</sup> investments, with US\$6.7 billion invested in the past five years,<sup>19</sup> most of which has been in developed countries. However, agriculture is currently the slowest sector in terms of adopting digital technologies, according to McKinsey's Industry Digitization Index.<sup>20</sup>

**Digital technologies have the potential to improve efficiency, equity, nutrition and health, and sustainability of the food system.** In terms of *efficiency*, digital technologies can: (i) improve the use of capital, including machinery and equipment, in the food system, thereby increasing its technical and allocative efficiency; (ii) facilitate the acquisition of skills and knowledge needed for agricultural production, thereby improving labor efficiency and the optimal use of inputs; (iii) improve farmers' decision making through accurate, timely, and location-specific price, weather, and agronomic data and information that will become increasingly important in the context of climate change; and (iv) reduce costs associated with matching producers and consumers, which will help expand output markets and improve

producer access to inputs. Improved production decision and production efficiency can improve farmer profits. In terms of improving *equity*, digital technologies have the potential to address unequal access to information, knowledge, technologies, and markets, and thereby improve relative incomes of poor people. In terms of improving *nutrition and health*, in one recent study, the use of mobile phones was associated with increases in household income, gender equality, and food and nutrition security. Positive nutrition effects occurred primarily through income and gender equality pathways.<sup>21</sup> In addition, digitally-enabled improved traceability can help increase food safety, with positive health effects. As regards environmental *sustainability* of the food system, digital technologies can improve use of natural capital such as water and land, and improve the use of inputs, such as fertilizers. For example, remote sensing technologies can measure water use and monitor net withdrawal of groundwater, which can help determine sustainable use targets for better irrigation water management.

**While digital technologies have many potential advantages, they also present risks that will need to be monitored and addressed to ensure broad benefits.** The World Bank's *World Development Report 2016* on the "Digital Dividend" details several risks, including: inequality of access and affordability; concentration of market power as regards e-commerce platforms, social networks, and search engines; issues related to data privacy, ownership and consumer protection; and cybersecurity breaches. These risks apply also to the food system. Two risks—inequality of access and data privacy—are highlighted here, and with market

concentration, are addressed in more detail in subsequent sections of the paper.

- **Inequality of access:** Digital technologies have the potential to reduce inequalities in the food system but may also potentially widen inequality. Uneven connectivity and broadband infrastructure lead to unequal opportunity. If digital technologies require more specific skills, the benefits may accrue disproportionately to those farmers that are positioned to take advantage of such opportunities.<sup>22,23,24</sup> If digital technologies require substantial investments, small-scale farmers may be excluded from their adoption and may see their relative competitiveness decrease. Costs of entry for some value chains may increase. For example, if retailers require suppliers of fresh produce such as leafy greens to apply real-time traceability using blockchain technology to increase response times in case of food-borne illness, supplier entry costs will rise, and those unable to meet those requirements will be excluded. The gender divide may also widen due to men's generally stronger socio-cultural access to new technologies than women. Even in richer countries, such as those in the EU, data show that within countries the use of e-government services is associated with higher education, employment, urban residence, being male, and broadband access. Support to small-scale farmers, particularly women, through skills development and entry cost can help reduce inequality risks.
- **Data privacy:** Digital technologies raise questions about the ownership and use of digital information acquired by these

technologies. Providers of digital applications and data storage platforms for actors in the food system, including farmers, are private enterprises that could potentially use these data in different ways, including making the data available to third parties. In addition, significant amounts of data on farming practices are generated off-farm through remote sensing via satellite imagery. Rules governing data ownership and use are often inadequate, which raises concerns about data misuse. There are ongoing efforts to develop workable arrangements that will give farmers sufficient confidence about data privacy and which are not overly restrictive for service providers.<sup>25</sup>

**While digital technologies offer an opportunity to improve food system outcomes, they are not a panacea.** Complementary investments are required to realize the potential

benefits of digital technologies, especially in developing countries, and to address the multiple constraints faced by farmers. These investments include: (i) complementary infrastructure such as roads, electricity, and post-harvest storage to improve access to markets and value addition; (ii) investment in skills and knowledge to improve farming practices in general, but also to improve digital literacy and enable farmers to better take advantage of digital technologies; (iii) farmer organizations that more effectively link farmers to markets; and (iv) access to financial services to help finance agricultural inputs and for savings mobilization, for which digital technologies can also help. Countries can also make significant policy improvements to increase incentives for investment in food systems that in turn may increase demand for digital technologies. Digital technologies should be seen as a complement to, rather than a substitute for, better policies.







## What digital technologies are helping to improve food system outcomes?

A range of digital technologies are currently facilitating improved communications, operations, and transactions across the food system, that are resulting in better informed and engaged consumers with more transparent value chains, smarter farms, and improved public services. This section provides some illustrative examples rather than an exhaustive list of digital technologies in the food system.

### Better informed and engaged consumers with more transparent value chains

Consumers are increasingly demanding more transparency in the products they buy, including product ingredients and information on sources and production methods. Digital technologies enable increased transparency

by improving product traceability, and better informing consumer choice as to price, nutrition, production practices, and environmental and biodiversity impacts. With increased transparency, consumers are increasingly influencing how food gets produced. The range of digital technologies improving value chain transparency includes distributed ledger technologies, smart contracts, food-sensing technologies, and e-platforms.

**Distributed ledger technologies (DLTs) and smart contracts have significant potential to increase efficiency and transparency in agricultural supply chains** by improving product traceability and integrity, contract certainty, proof/verification of geographic origin, and compliance with sanitary and phytosanitary requirements. DLTs and smart contracts also have potential to improve implementation and monitoring

of World Trade Organization agreements and key provisions relating to agricultural trade. DLTs can ensure that gains from trade accrue more directly to producers and consumers.<sup>26</sup> Traceability can reduce food loss in food systems, with estimated gains of up to 30 million tons annually if DLTs were to be incorporated in half of the world's supply chains.<sup>27</sup> For net environmental effects, emissions reductions from decreased food production associated with reduced food loss would need to be assessed against potential increases in emissions arising from DLT applications' energy usage. The use of blockchain in the food system is still at an early stage, but there have been a number of successful pilot tests of its use. For example, the French supermarket chain Carrefour uses blockchain to provide consumers with detailed information on chicken purchases, including veterinary treatments and freshness.<sup>28</sup> To ensure their scalability and accessibility, however, DLTs solutions require appropriate ecosystems. While some of the elements of such ecosystems are technology-specific, they also largely entail enabling policy, regulatory and institutional conditions as well as basic requirements relating to infrastructure, literacy, and digital and network coverage.<sup>29</sup>

**Food-sensing technologies are increasingly used to identify food quality, and monitor food safety.** Food-sensing technologies are using cost-efficient and non-invasive approaches such as spectroscopy and image analysis to provide information on biometric and biochemical features of food (such as size, shape, moisture, protein and fat content, and level of contamination). For example, hyperspectral spectroscopy has

identified with up to a 99.67 percent success rate contamination in red meat.<sup>30</sup> FruitQC, a Telspec application, provides information on quality, ripeness, and flavor of fresh fruit in less than 15 seconds.<sup>31</sup> By providing information on food quality, food sensing could reduce food waste by 5 to 7 percent.<sup>32</sup> With the cost of food-sensing technologies rapidly declining, they could be increasingly used to reduce expenses caused by food safety issues, which are particularly important in low- and middle-income economies where foodborne illnesses cost US\$110 billion each year.<sup>33</sup> Food-sensing technologies are becoming increasingly accessible through mobile devices for both consumers and supply-chain stakeholders, and could potentially provide inspection of a much larger share of commercially available food.<sup>34</sup> However, even for the most advanced food-sensing applications, the algorithms should be periodically validated and recalibrated by traditional laboratory methods to improve accuracy and precision.

**Digitally-enabled marketplaces for agricultural products (e-platforms) can potentially shorten agricultural value chains, provide access to new markets, reduce transaction costs, improve price transparency, and offer small and medium enterprises (SMEs) new business opportunities.** The power of e-platforms lies in the significantly reduced search cost of matching producers with consumers and lenders with borrowers, and their capacity to transfer and distribute risk. This process has the potential to sharply reduce past market failures and profoundly reshape value chains. In directly linking producers to consumers, e-platforms have the potential to shorten value chains

for some products. Lower search costs help farmers bypass middlemen and improve agricultural market performance.<sup>35,36,37</sup> According to the Department of Market System Development at China's Ministry of Commerce, the total online sales volume of agricultural products in China reached over RMB 240 billion in 2017 (about US\$36 billion), representing a 53 percent year-on-year increase. As of 2017, in China there were 9.85 million online shops operated by rural farmers and employing over 280 million people. China's e-commerce giant, Alibaba, has launched several initiatives to become a one-stop-shop for SMEs conducting business online, including online marketplaces, back-end e-commerce merchant services, and a cloud-computing e-commerce platform. Nevertheless, according to a recent survey in rural China, in 2016 only 1.5 percent of rural households sold agriculture products, mainly vegetables and fruit, through the Internet.<sup>38</sup> Lack of knowledge and skills, and low trust in online transactions were the main reasons for low adoption. Storage and transportation of fresh produce present another challenge to growing remote e-commerce sales. If these aspects are addressed, there is potential for significant growth.

## Smarter farms

Digital technologies can help improve farm profits by improving productivity and resilience through more efficient use of land and water, improved access to capital, reduced product price dispersion across markets, and in some circumstances may lead to higher product prices and a higher share of retail prices for farmers. Relevant digital

technologies include e-extension, precision agriculture (remote sensing), matching markets for mechanization services and other inputs, improved access to market price information and finance, and improved certification for export markets.

**E-extension services can help raise farm profits and provide a cost-effective way to reach a greater number of farmers.** They can provide farmers with relevant and real-time access to information on how to resolve both general and specific problems, ranging from sustainable farming practices, climate-smart solutions, and market access. Extension agents can use a combination of digital technologies to reduce the cost and increase the frequency of interaction with farmers.<sup>39,40</sup> For example, in Bangladesh, farmer-to-farmer videos on rice seed production produced for women led to lower production costs from lower seeding rates, and a 15 percent increase in rice yields.<sup>41</sup> Plantix, a mobile crop advisory application for farmers, provides a quick diagnosis of plant diseases, pests, and nutrient deficiencies based on a photograph taken by a smartphone. Digital Green, which works in South Asia, Latin America, and Sub-Saharan Africa, has produced and disseminated over 5,000 locally relevant videos in more than 50 languages, enabling farmers to share knowledge on agricultural production practices with one another<sup>42</sup> that provides a relatively cost-effective way of helping increase adoption of improved production practices.<sup>43</sup> These videos are primarily screened off-line in communities that have limited electricity and Internet connectivity. While there are various forms of e-extension, many are fairly recent, and evaluation is still ongoing as to which forms of agricultural e-extension services



work best, and under what conditions.<sup>44</sup> In general, for successful results, e-extension services need to provide timely, localized, and customized information that addresses specific farming concerns in a comprehensible format and appropriate language.<sup>45,46</sup> At the same time, digital technologies are often a complement to field advisory visits, rather than a substitute. Used in combination with other more traditional forms of extension may make e-extension services even more useful to farmers.

**Precision agriculture can improve the quantity and quality of agricultural output while reducing input usage (such as water, energy, fertilizers, and pesticides), thereby generating climate benefits, while also increasing time efficiency by performing farming practices remotely.** Reducing the use of inputs such as fertilizers and pesticides offers positive environmental effects. Precision farming uses data received from global positioning systems, satellite and aerial imagery, and sensors (for example, sensors for soil conditions, ground water levels, and precipitation detectors) to enable a range of precision agriculture applications. In the United States, precision agriculture technologies were used on 30 to 50 percent of corn and soybean acreage in 2010–2012. Impacts on farm profits were positive but small, with adoption more likely on larger farms.<sup>47</sup> As precision agriculture technologies become easier to implement they could help improve incomes on smaller farms. The Nano Ganesh system in Pune, India, uses digital applications for irrigation systems to allow control of irrigation pumps remotely, by mobile phone, which saves farmers water, energy, and time.<sup>48</sup> In addition to potential

productivity gains and cost savings, precision farming via satellite technology enables governments to study how agricultural practices affect the ecosystem, develop better regulations,<sup>49</sup> and enforce sustainable land management practices, as in Uruguay.<sup>50</sup> Even though many high-tech precision tools are more accessible for large-scale farms that can afford significant investments in technology, the situation is changing as access to technologies and their delivery become cheaper and more affordable for smallholders. For example, the International Maize and Wheat Improvement Center (CIMMYT) has been testing variable rate fertilizer application kits for smallholder farmers.<sup>51</sup>

**Matching markets can improve smallholder farmers' access to mechanization services and, in turn, reduce unit costs and increase competitiveness.** Physical capital, such as farm machinery, is a key driver of on-farm productivity. However, the high upfront cost of farm machinery often puts it out of reach of smallholder farmers. Digital platforms can create new markets for machinery rentals by: (i) providing more affordable access to physical capital for smallholder farmers, and (ii) putting underused assets to work by matching suppliers of machinery rental services with farmers wanting these services, just as Uber matches drivers with customers for taxi services. As the marginal cost of matching buyers and sellers through digital platforms is extremely low, this service has the potential to reduce unit costs of machinery rental services through saved transaction and search costs. A study in Zambia showed that hiring tractor services leads to higher farm profit, by enabling farmers to expand their cultivated area and,

consequently, increase their income.<sup>52</sup> Well-known examples include: TroTro Tractor, Ghana's platform to connect tractor operators with farmers; Trringo, India's foremost tractor and farm equipment rental service; and Hello Tractor, which matches tractor owners with smallholder farmers in need of tractor services via simple text messages in Ghana, Kenya, and Nigeria.

**Under certain conditions, improved access to market information via mobile phone can help increase farmers' sales and prices, and reduce price dispersions across markets.**

Increased access to information about market prices via mobile phone can increase farmers' bargaining power vis-a-vis traders on farm gate product sales. This process, in turn, can help increase farmers' shares of retail prices and farmer sales.<sup>53,54</sup> For example, analysis shows that access via mobile phone short message service (SMS) to market price information on local crops in the central highlands of Peru increased farmers' sales prices by 13 to 14 percent relative to counterparts without access to this information.<sup>55</sup> For sales to markets, market information via mobile phones can better inform farmers and traders where prices are highest. The latter market arbitrage can help reduce price dispersions across markets,<sup>56,57</sup> and reduce relative oversupply to specific markets thereby potentially lowering food loss and waste. Not all studies show that these effects are significant. Impacts on farmer prices from increased market information via mobile phones tend to be dependent on local conditions, for example: (i) impacts tend to be more significant, particularly for medium-to-high value commodities, where mobile phone penetration is lower; and

(ii) the specific content of the information has greater impact as mobile phone penetration and access to information increases.<sup>58</sup> In these situations, content customized to higher value commodities and varieties produced by farmers in specific locations had higher impact.<sup>59</sup>

**The digitization of transactions and payments, and data analytics, can improve access to finance by smallholder farmers.**

Agricultural finance can facilitate farmer access to improved inputs and technologies. Yet, less than 10 percent of smallholder farmers worldwide have access to formal credit.<sup>60</sup> Digital technologies improve access to finance through a combination of lowering operating costs and offering better ways to assess weather, market, and credit risk. Financial institutions and agribusinesses can use digital transaction records to process and facilitate credit. Mobile phone-based digital financial services have the potential to reach formerly unbanked populations as mobile phone and Internet usage expands. In addition, numerous studies show that digital financial solutions have a positive and significant effect on annual household input use, agricultural commercialization, and household income.<sup>61,62</sup> New FinTech solutions are developing rapidly. M-PESA represents a prominent example—the Kenya mobile phone-based payment system was introduced in 2007 and, by 2009, had reached 65 percent of Kenyan households. Furthermore, it is estimated, that M-PESA has lifted 2 percent of rural Kenyan households out of poverty.<sup>63</sup> While FinTech firms still play a negligible role in global commercial lending, digital technologies in the global financial sector will gain growing

importance over the coming years, including in the food system.<sup>64</sup> For example, big data<sup>65</sup> and advanced analytics can significantly reduce the cost of establishing creditworthiness of farmers and assessing insurance risk. These lower costs can potentially lower interest rates and insurance premiums for farmers thereby increasing access to these financial services. Farmdrive in Kenya, and Harvesting in Uganda, are examples of companies using data analytics to assess farmers' creditworthiness for financing.

## Improved public services

Digital technologies can help improve public services in the food system. Beyond e-extension services detailed in the previous section, such services include better targeted government-to-person payments, improved risk management, and monitoring and evaluation.

**Digital technologies can be used to better target government-to-person payments, improving distribution efficiency and transparency.** Through the introduction of a digital system in Estonia, the time spent applying for agricultural subsidies at the Agricultural Registers and Information Board decreased from 300 minutes to 45 minutes.<sup>66</sup> In Nigeria, the government reached a higher number of recipients with lower cost and lower leakage through an e-wallet program for subsidized fertilizers. Prior to this program, in 2011, the government spent approximately US\$180 million for 600,000–800,000 smallholders, most of which never reached the intended beneficiaries.<sup>67</sup> In 2013, with the e-wallet digital

payment system, the government reached 4.3 million smallholders at a cost of approximately US\$96 million.<sup>68</sup> This system also facilitated financial inclusion of farmers and expanded private sector opportunities.<sup>69</sup> A recent review of pilot e-voucher programs for subsidized farm inputs in Guinea, Mali, and Niger highlighted several lessons for implementation of these types of programs. These lessons include the following: the importance of mobile network coverage; actual possession of mobile phones by intended beneficiaries, particularly women; promoting literacy and knowledge about how the program works; and organization of procurement and agro-dealers to ensure availability of farm inputs at the right time of the agricultural season.<sup>70</sup>

**Remote sensing and big data applications are being increasingly used for enhanced management and efficiency, and also to mitigate risk.** These applications include automated early warning systems for crop or livestock health, related to weather, pests and diseases that can facilitate proactive and timely management responses. Advances in data management and machine learning<sup>71</sup> now make it possible to integrate and analyze billions of data points (analog and digital, ground-based and remotely sensed) at high-spatial and temporal resolution. For example, the World Bank Agriculture Observatory is accessing ground-based hydrometeorological data (very sparse in most developing countries) and high-density weather satellite radar platforms, and applying machine learning to generate a continuous weather surface across the earth's croplands. The resulting weather data comprise 7 billion data points generated daily by

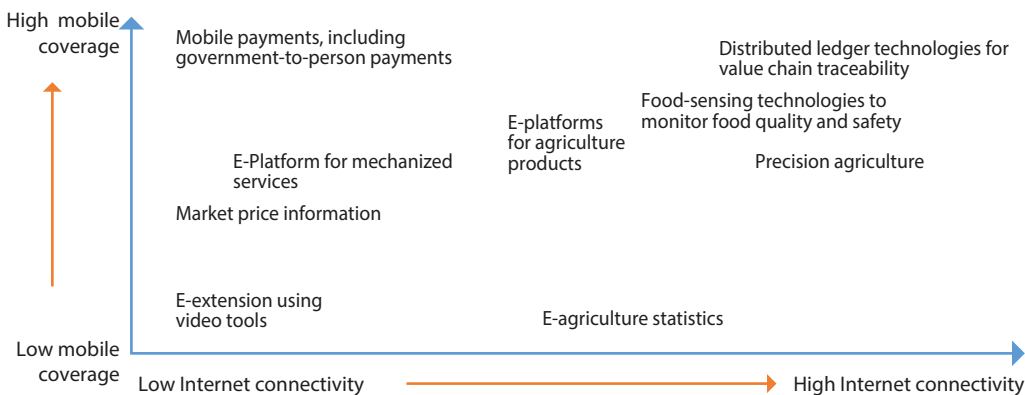


1.5 million virtual weather stations across the world and updated four times a day, to generate “real-time” weather data at intervals of nine kilometers across global agricultural land. This data surface represents a disruptive approach to the traditional method of relying solely on ground-based hydrometeorological stations that need to be procured, installed, calibrated, and maintained, even before the data are accessed, analyzed, and synthesized. By coupling the high resolution weather surface with cropping calendars, it is possible to make real-time assessments of crop performance and to take proactive management risk-mitigation interventions and decision support across the entire value chain, comprising farmers, input suppliers, logistics providers, markets, and policy makers. Because early projections of crop yield anomalies are possible at the sub-national, national, regional, and even global level, the Agriculture Observatory platform can provide early warning of potential food shocks several months in advance of normal harvest periods. Information and analysis from the Agriculture Observatory are being used to guide the design and implementation of agriculture projects. National Agriculture Observatories are in operation or are being set up in Ethiopia, Kenya, Russia, Zambia, and Zimbabwe, in close collaboration with national agricultural and meteorological agencies.

**Digital technologies offer a broad spectrum of tools and data to enhance monitoring and evaluation of outcomes in agriculture.** The uptake of digital tools and consequent data generation in agriculture can help enable more cost-effective monitoring and evaluation (M&E) of results. While

digital survey tools have long been used to lower the cost of project-level data collection, more advanced technologies such as remote sensing can bring additional efficiencies to M&E. For example, satellite earth observation provides unbiased, consistent, and timely information on whether investments in agricultural development are taking place in a sustainable and effective manner. Satellite data can thereby promote better transparency, responsibility, and accountability to impact assessments of agricultural investments on crop production and water management. The World Bank supported the Resilient Agriculture and Integrated Water Resources Management Project in the Dominican Republic, which used drones to monitor changes in the physical condition of irrigation infrastructure in 1,200 hectares (ha) of rice fields. The pilot study was designed to understand the value, including cost-effectiveness and feasibility, of using drones for M&E in infrastructure development interventions relative to other methods such as satellite imagery, aerial photography, and physical inspection. Drones provided higher resolution, easy deployment, and eliminated problems relating to cloud cover interference that occur with satellite imagery and aerial photography. However, as drones cover relatively smaller areas as they can only make a finite number of flights per day, and have a higher regulatory burden, they are more cost-effective for smaller areas. Another tool for monitoring and evaluation is the Geo-Enabling Initiative for Monitoring and Supervision (GEMS). GEMS is a smart-phone-based system that enables monitoring agents to enter data on implementation progress, including photos, and is automatically time stamped with GPS

**FIGURE 1:** Continuum of digital technology opportunities (illustrative)



coordinates. The information can be entered off-line and, when a mobile connection is available, is uploaded to a central database. GEMS is being increasingly used to monitor implementation progress of projects in fragile situations, such as in Democratic Republic of Congo and the Central African Republic.

**The set of digital technologies across value chains, farms, and public services highlighted in this section require different levels of mobile phone and Internet connectivity.** For example, agricultural extension and farmer-to-farmer learning provided by digital videos can be provided off-line with no need for mobile or Internet

connectivity. Mobile-phone-based market price information, e-platforms for mechanized services (such as Hello Tractor), and government-to-person payments require access to mobile networks but low Internet connectivity, while e-statistics require Internet connectivity but low mobile coverage. Additionally, some technologies are best suited to environments with both high mobile coverage and high Internet connectivity such as distributed ledger technologies for value chain traceability. The continuum of digital technologies offers opportunities across a range of mobile phone and Internet connectivity (figure 1). Skills needs also vary across this continuum, an aspect that is addressed in the next section of the paper.



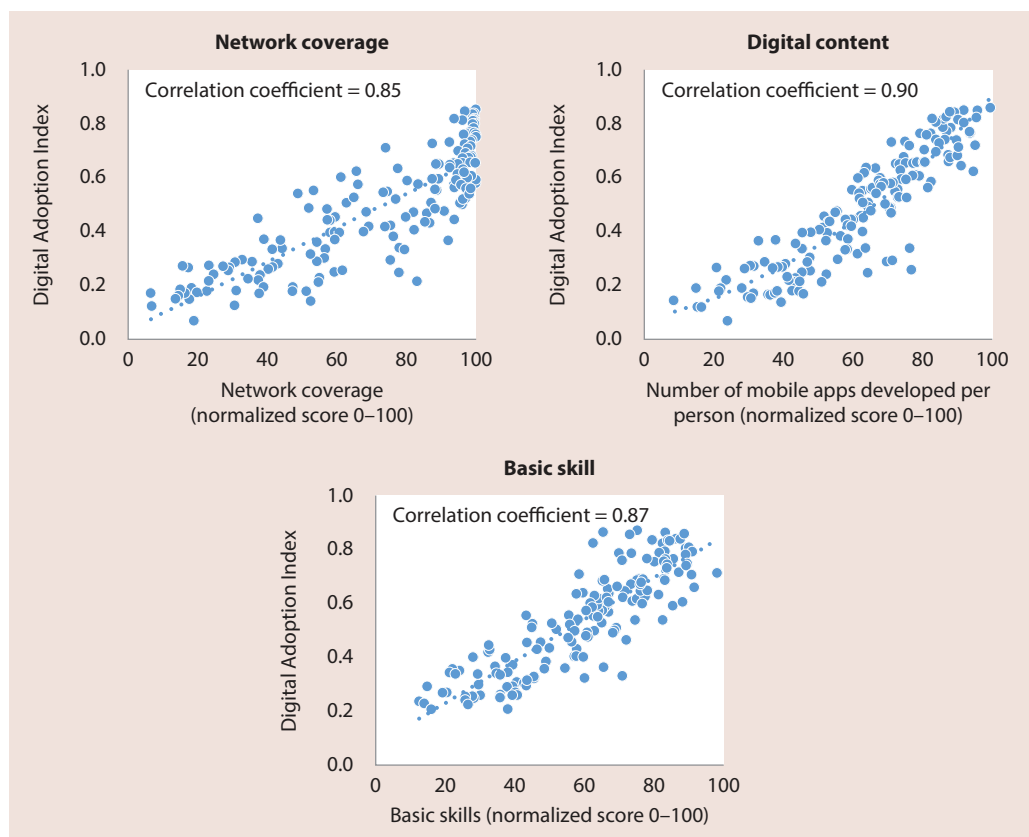
## What public actions can facilitate broader adoption of digital technologies and harness their impacts on food system outcomes?

**The adoption of digital technologies in aggregate is affected by both supply factors (network coverage and digital content), and demand factors (including skills/knowledge).** These factors have strong positive correlations with country level digital adoption (box 1). While data on these correlates are not available for separate geographies or sectors, and represent aggregate countrywide data, a similar general pattern is likely for the food system. However, adoption rates in agriculture have been lower than other sectors according to the McKinsey Industry Digitization Index. This situation is likely reflective of the lower mobile coverage and Internet connectivity in rural areas where farmers and many agribusinesses operate, and the lower levels of skills in rural areas. The development of digital applications or content, indicative of digital entrepreneurship, is correlated to network coverage (0.84 correlation coefficient between network

coverage and number of mobile applications developed per person). As network coverage increases, so do potential users of digital applications, which increases the incentives of entrepreneurs to develop digital applications or content. Knowledge/skills impact digital adoption in two primary ways. First, the knowledge/skills of end users, such as farmers, affect demand for digital technologies. For example, farmers have to know that a certain technology exists, believe it will help them (demonstration of effectiveness), and learn how to use it. Second, the knowledge/skills of entrepreneurs that develop digital technologies impacts digital adoption (the correlation coefficient of basic skills and mobile applications developed per person was 0.89 using 2017 cross-country data). Digital technologies can be designed in a way that requires low-level skills and literacy for its use, for example with voice and touch screen functionality.



## BOX 1: Digital adoption correlates



Sources: World Bank and GSMA 2017 country level data.

**Even with no or low mobile phone coverage and Internet connectivity, there are still opportunities for digital technologies.** Digital technologies are advancing rapidly and there are now off-line technologies that can help poor and even illiterate farmers improve production practices with no or limited mobile phone coverage and Internet connectivity.

**The Maximizing Finance for Development (MFD) framework can help identify public actions needed to facilitate**

**broader adoption of digital technologies and harness their impact on food system outcomes.** MFD looks for ways to crowd-in private resources to help achieve development goals, while optimizing the use of scarce public resources. As digital technologies are primarily generated by the private sector, and as the farmers and agribusinesses adopting these technologies are also private actors, MFD can help identify entry points for public sector action to facilitate broader adoption of digital technologies and harness their impacts on food system

outcomes.<sup>72</sup> A sequence of questions about rural network coverage, digital applications and content, and private end-user adoption can help identify appropriate public actions. These questions include: (i) Is the private sector investing in digital technologies? (ii) If not, is it because there is limited space for private sector activity as a result of restrictions to competition, public sector dominance, or private sector monopolies? (iii) If not, is it because of policy and regulatory weaknesses or gaps? (iv) If not, can public investment help crowd-in private investment? (table 1). While these questions proceed in sequence, the intention is not to stop if the answer to a question is affirmative, but to answer all the questions and ensure a complete assessment and identification of public policy entry points. Once these have been identified, implementation of public policy and regulatory changes, and public investments need not be sequential. Indeed, they are likely to be simultaneous or multi-staged. Cutting across these aspects are considerations for public policies to address efficiency, equity, and environmental sustainability aspects, as well as addressing the risks of digital technologies highlighted in the earlier section, such as data privacy, inequality, and concentration of market power. Table 1 provides a brief assessment of the first question, and if the answer to one of the other questions is yes, it provides potential entry points for public sector actions. Factors included in table 1 are expanded on in the subsequent text. The intent is not to provide an exhaustive treatment of each factor, but rather provide a range of potential entry points for action, and in the process, refer to ongoing and relevant World Bank work.

## Expand rural network coverage

**Rural network coverage is often relatively low but varies significantly across countries with similar income levels:**

While there are off-line digital technologies, as discussed in the previous section, network coverage increases the opportunity set of digital mobile technologies for people residing in rural areas. In addition, the type of network available influences the type of digital application that can be used. For example, second generation (2G) networks are more suited for voice and text messaging, while third generation (3G) and fourth generation (4G) networks allow for broader applications and use of smart phones. While, on average, more than 90 percent of the population in high income countries have network coverage, only about 50 percent of the population in low-income countries do, on average. For example, about three-quarters of the population in Chad have no network coverage, whereas in Mozambique and the Democratic Republic of Congo, about 60 percent have no coverage.<sup>73</sup> While more than 60 percent of Burkina Faso's population have 2G coverage, only 25 percent have 3G coverage or faster.<sup>74</sup> The extent of network coverage across countries, among other factors, is likely affected by GDP per capita levels, country size, population distribution, and policies.<sup>75</sup> All else held equal, countries that are richer, smaller, and with more concentrated populations tend to have mobile network coverage rolled out to a larger share of the population.<sup>76</sup> By contrast, countries with more dispersed populations, as reflected in a relatively higher share of the population living in rural areas, tend to have

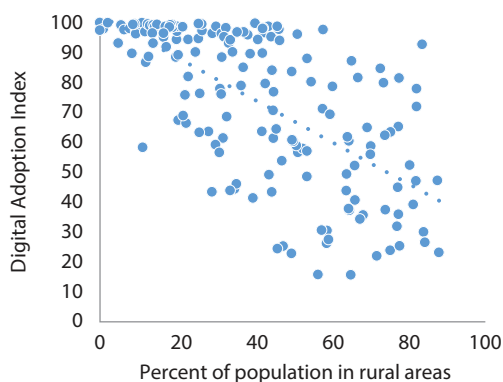
**TABLE 1:** Potential entry points for public-sector actions to facilitate broader adoption of digital technologies and harness their impacts on food system outcomes

MFD cascade of questions:	Supply-side factors		Demand-side factors
	Expand rural network coverage (expand digital infrastructure)	Develop relevant digital applications (foster digital entrepreneurship)	Facilitate demand for digital technologies in the food system (particularly smallholder farmers)
Is the private sector doing it?	<ul style="list-style-type: none"> <li>■ &gt;90% coverage in high income countries</li> <li>■ 50% coverage in low-income countries (even lower for 3G or faster networks)</li> </ul>	<ul style="list-style-type: none"> <li>■ Increase in ag-tech investment over last 10 years; growth in ag-tech start-ups in Africa over the past two years</li> <li>■ Significant variation across countries</li> </ul>	<ul style="list-style-type: none"> <li>■ Higher farmer adoption of digital technologies in high-income countries relative to low-income countries; and higher adoption rates on larger farms</li> </ul>
If not, then is it because of limited space for private sector activity?	<ul style="list-style-type: none"> <li>■ Foster competition among telecoms (competition is associated with more extensive rural coverage)</li> </ul>	<ul style="list-style-type: none"> <li>■ Lower entry costs to facilitate competition among digital platforms</li> </ul>	
If not, then is it because of policy and regulatory gaps and weaknesses?	<p>To help lower the cost of providing rural coverage:</p> <ul style="list-style-type: none"> <li>■ Adopt a spectrum policy that boosts connectivity</li> <li>■ Lower infrastructure taxes/duties</li> <li>■ Allow infrastructure sharing</li> <li>■ Ensure consistency/streamline local level regulations</li> <li>■ Reduce policy/regulatory uncertainty</li> </ul>	<ul style="list-style-type: none"> <li>■ Improve the enabling environment for business development</li> <li>■ Design digital regulations around functionality</li> <li>■ Clarify data ownership</li> <li>■ Develop governance arrangements for open data</li> <li>■ Invest in open data that have public good characteristics</li> </ul>	<ul style="list-style-type: none"> <li>■ Improve farmers' incentives to invest</li> <li>■ Develop data governance arrangements that build users' confidence and trust in digital technologies</li> </ul>
If not, then can public investment help crowd-in private investment?	<ul style="list-style-type: none"> <li>■ Invest in complementary infrastructure</li> <li>■ As a last resort, subsidize service providers to offset higher costs of rolling out rural coverage</li> </ul>	<ul style="list-style-type: none"> <li>■ Support skills development</li> <li>■ Improve access to finance for start-up and early maturity ag-tech enterprises</li> <li>■ Support increased use of digital payments</li> </ul>	<ul style="list-style-type: none"> <li>■ Support skills development for vulnerable groups</li> <li>■ Develop relevant, customized tools</li> <li>■ Reduce costs of technology adoption</li> <li>■ Improve access to finance</li> <li>■ Invest in complementary infrastructure</li> </ul>
		<ul style="list-style-type: none"> <li>■ Support development of digital farmer identification</li> </ul>	

lower network coverage (figure 2). While coverage in rural areas tends to be lower than in urban areas, some low-income countries

have managed to achieve relatively high levels of rural coverage. For example, more than 90 percent of Rwanda's population have 3G

**FIGURE 2: Network Coverage**



Sources: World Bank and GSMA country-level data.

coverage and 85 percent of the population in Kenya have 3G coverage. The rural population comprises 83 percent and 73 percent of the total population in Rwanda and Kenya respectively, suggesting high rural coverage.<sup>77</sup> Carefully designed policies and regulations can promote greater expansion of networks to rural areas.

**Expand the space for private sector activity:** Evidence from more than 200 countries over 15 years shows that network competition has helped expand network coverage.<sup>78</sup> Taking into account other factors such as GDP per capita; and population size, density, and distribution, analysis shows that population coverage was, on average, 12 percentage points higher in countries with network competition compared to countries served by a single network provider; population coverage for 3G was, on average, 36 percentage points higher, and population coverage increased three times as fast in countries with network competition.<sup>79</sup> While increased competition in the telecoms sector is associated with increased rural coverage in low-income countries, competition

policy alone is unlikely to ensure parity in urban and rural costs and coverage.<sup>80</sup>

**Policy and regulatory entry points to lower costs:** At lower population densities, unit costs of telecom service providers per user are higher. In addition, rural areas often have higher installation and maintenance costs, greater distances from main roads, more uneven terrain,<sup>81</sup> and lack of electricity. This situation results in higher prices in rural areas, or a lack of services if demand is insufficient to cover costs. Potential public policy entry points to expand rural coverage in developing countries include: (i) ensuring sufficient release of spectrum (frequencies allocated for communications over the airwaves) and designing associated spectrum policy with the aim of boosting rural connectivity;<sup>82</sup> (ii) lowering infrastructure taxes and/or import duties to lower costs; (iii) making consideration for infrastructure sharing, including mast or tower sharing, as a way to lower costs, and allowing customers to roam between networks; and (iv) ensuring consistency and streamlining of regulations at the local level on site deployments.<sup>83</sup>

**Reduce policy uncertainty:** Reducing macroeconomic and political stability, and ensuring more reliable policies reduces private sector investment risks. In addition, regulatory systems that provide greater certainty for investment serve as a necessary condition for the expansion of digital infrastructure in rural areas. According to the World Bank's *Enabling the Business of Agriculture* report,<sup>84</sup> countries with higher quality ICT regulations<sup>85</sup> tend to also perform well on the GSMA Mobile Connectivity Index. In



addition to high transaction costs, arbitrary regulatory changes contribute to high prices for end-users in rural areas.<sup>86</sup>

**Use public investment to help crowd-in private investment:** Complementary investments such as rural electrification, including local solar energy sources, can address power supply constraints in rural areas. Countries such as the United States have also provided subsidies to services providers to offset the higher cost to extend broadband coverage to rural areas.<sup>87,88</sup>

## Foster digital entrepreneurship

**Digital entrepreneurship varies significantly across countries, with recent growth in ag-tech startups.** There is a positive correlation between the number of digital applications developed per person and network coverage,<sup>89</sup> and this correlation is likely indicative of the importance of an expanding potential client base for developers. However, there is a fairly large variation across countries in the number of digital applications developed per person, per level of network coverage. Part of this difference may be due to differing enabling environments for digital entrepreneurship in these countries. There has been significant growth in ag-tech investments in the past 10 years,<sup>90</sup> and in the past two years, significant growth in ag-tech startups in Africa.<sup>91</sup> This section highlights some public sector entry points to foster digital entrepreneurship and investment in the food system, and to address some of the risks. The World Bank has ongoing work on this topic focusing on the Africa region.

**Development of digital applications is influenced by a broad set of country conditions.** These conditions include supply-side factors, such as: digital infrastructure, including network coverage; other infrastructure such as roads and electricity; the enabling environment for entrepreneurship; skills development; and access to financing. Also important are demand-side factors, including support for smallholder farmers and agribusinesses to adopt digital technologies. A vibrant innovation ecosystem also requires collaboration among companies, investors, governments, and development partners. Understanding the binding constraints among these sets of conditions can help inform what the public sector can do to improve the innovation ecosystem for ag-tech entrepreneurs. While some of these aspects are relevant for all entrepreneurship in the food system, others are specific to digital development. For example, there are ongoing questions about the risks associated with market concentration in digital platforms, data privacy, and consumer protection. Digital registries are also one solution for better targeting services, and better informing development of digital applications. Per the MFD framework in table 1, this section discusses the space for private sector activity, including policies and regulations, as well as public investments to crowd-in private investment in digital application and content with a particular focus on addressing such risks as market concentration and data governance.

**Lower entry costs for private sector competition in digital platforms.** There is a risk that digital technologies can increase the concentration of market power. Prominent examples include Facebook among social

network providers, Amazon among e-commerce marketplaces, and Google among search engines. There has been much debate on this topic which is beyond the scope of this paper to try to resolve. Nevertheless, a key goal is to keep market entry costs low for new entrants and switching costs low for consumers.<sup>92</sup> Low entry costs allow for dynamic development and competition, so that new players with superior business models and innovation can enter a specific market and disrupt the existing market leader. However, developers of new digital solutions often face high up-front costs associated with software, data storage, analytics, and security, which deter competition. In addition, network effects and switching costs can create barriers to scale for new entrants; the more users connected via one network (such as for buyer-producer platforms within a value chain), the smaller the incentive for those users to switch to another network. These aspects make regulation a significant challenge. In some cases, regulations have been expanded to curb excessive market concentration, as was the case for M-Pesa, a highly successful money transfer system rolled out in Kenya by Safaricom, a mobile services provider. Initially, banking regulators' hands-off approach contributed to the rapid growth of M-Pesa. Through exclusivity arrangements, M-Pesa agents could only offer products and services within the M-Pesa network, which locked agents and most users into a single network. Given Safaricom's dominant market share, the exclusivity contracts posed an entry barrier for other telecom operators, and the Kenya Competition Authority expunged the exclusivity agreements in 2014, permitting M-Pesa agents to work with other mobile

operators. The cost of money transfers subsequently declined.<sup>93</sup>

**Improve the enabling environment for business development.** Macroeconomic stability and peace are key conditions for private enterprise development. In addition, an environment characterized by unclear property rights, frequent policy change and reversal, uncertain contract enforcement, and high corruption translates into lower investment and growth.<sup>94</sup> Supportive policies such as making it easy to start a business, business-friendly tax policy, and strong patent protection can also help facilitate entrepreneurship.

**Design digital regulations around functionality and contestability.** The growing complexity of digital ecosystems underpinning digitization of food systems, as well as an exponential increase in the volume and speed with which data are collected and analyzed add to the challenges of designing appropriate policy and regulatory systems. Growing innovation and rapid market changes make regulations both more complex and more prone to quickly become obsolete. On the other hand, existing policy and regulatory frameworks are often unsuited to addressing concerns, such as data privacy and ownership issues, arising from rapid digitization. All this results in a higher likelihood of regulatory uncertainty, higher compliance costs, and lower levels of technology adoption. According to a recent PwC survey,<sup>95</sup> regulatory uncertainty around blockchain-based solutions was identified as a major scale-up challenge across various sectors. For the new regulatory frameworks to address these challenges, regulations and regulatory institutions should be re-designed

around the principles of contestability—that is, to address risks associated with market concentration—and functionality focusing on the ultimate policy objectives (for example, cost effectiveness or privacy protection), rather than on the technologies. Regulations should be dynamic and focus on principles that allow ex-post enforcement of broad rules rather than detailed ex-ante prescriptions. Lastly, new regulatory frameworks should recognize that many current regulations may be outdated, and the new digital economy may require a clean slate approach to re-evaluate existing and/or new regulations.<sup>96</sup>

**Clarify data ownership.** The economic value of data in food systems increases as they are aggregated, creating important policy and regulatory issues related to individual versus aggregate data ownership and use rights that are important for both developers of digital applications and farmers. Furthermore, defining data ownership and data use rights becomes increasingly complicated as the number of data users increases. In the event that data are generated using equipment owned by a farmer, defining data ownership rights is a straightforward task. However, this is not the case in a situation in which these data are aggregated and transmitted to cloud storage that can subsequently transfer them to a third party. Across the developed world, legal and regulatory frameworks around agricultural data ownership remain piecemeal and ad hoc. For example, in the United States and Canada, existing law does not recognize agricultural data as physical or intellectual property. As such, data ownership is not clearly defined. Nevertheless, countries have been experimenting with

different approaches to address data ownership issues. For example, U.S. and New Zealand agricultural sectors have been using voluntary industry standards to establish an understanding between farmers and service providers that use farm data on data ownership.<sup>97</sup> In 2018, an EU coalition of agri-food associations introduced a joint EU Code of Conduct on agricultural data sharing.<sup>98</sup>

**Develop governance arrangements for open data.** Policy and regulatory frameworks guiding aspects of data privacy and ownership also serve as major factors in enabling access and use of open data in agriculture, this includes government-to-private and private-to-private data sharing. Advantages of open data are numerous—they can advance innovation, serve as a platform for entrepreneurship, and increase transparency and accountability in the food system. To reap such benefits, however, certain challenges must be addressed,<sup>99</sup> including both technical and legal. To facilitate the use of open data, standards need to be designed to ensure privacy of individual data through effective anonymization while also ensuring its interoperability. Also, a certain level of infrastructure needs to be in place to enable the scaling up of open data initiatives. Properly designed data governance frameworks serve an integral role in enabling open data availability and use. While there is no single governance solution for open data in agriculture, Global Open Data for Agriculture and Nutrition identifies four possible governance strategies, namely: i) inter-institutional cooperation to build consensus about data ownership; ii) model frameworks adopted at the local, national, and regional levels; iii) social certification schemes that leverage the

power of ethical consumption, and iv) reaching an international agreement on ownership of open data.

**Invest in open data that have public good characteristics.** Invest in agricultural statistics and agroclimatic data that can be used by all, including creative entrepreneurs. Making these data available would reduce the cost of development and scaling up of novel digital applications, as developers would not have to devote resources to data collection. Public investment in agricultural statistics and agroclimatic data is likely an under-appreciated driver of the development of new digital applications to better meet the needs of smallholders. It is an open question whether there is a need for direct subsidies to entrepreneurs to develop applications for low-income farms and agri-SMEs, as such activities will become more profitable once low-income owners of farms and firms are digitally connected, and entrepreneurs are able to develop more relevant applications with increased availability of information.<sup>100</sup>

**Support skills development.** The number of digital applications developed per person is highly correlated with basic skills (in 2017, the cross-country correlation coefficient was 0.89).<sup>101</sup> Skills development can foster digital entrepreneurship. Incorporating more entrepreneurial and digital technology content in the curricula of agricultural universities and training institutes, together with associated teaching staff, could help develop skill sets needed to foster digital development in the food system. Mentoring and ongoing business advisory programs for enterprise development tend to be more effective than a one-off training. For example,

Twiga Foods in Kenya, a five-year-old company that uses a technology platform to improve the supply chain from farmers to markets, has effectively benefited from mentorship programs (Google Launchpad and GSMA Ecosystem). The Africa Agriculture Incubators Network (AAIN) is a network of companies that supports agriculture start-ups via technical support and mentorship, including help in preparing business proposals to pitch to investors. Entrepreneurship programs that combine interventions (mentoring or coaching, finance, and access to markets), addressing the multiple constraints that entrepreneurs face, tend to be more effective than single-intervention programs.<sup>102</sup> While a recent global analysis of youth-targeted interventions found that only about one-third showed a significant positive impact on employment or earnings, in low- and middle-income countries such programs have been more successful, and skills training and entrepreneurship programs seem to have had a higher impact.<sup>103</sup> Involving the private sector in program delivery is associated with improved impacts.

**Improve access to finance for start-up and early maturity AgTech enterprises.**

Access to finance is an important ingredient in successful start-up and scaling of digital technology enterprises. Early maturity enterprises need to rely mainly on financing from family or friends, venture capital, or commercial finance blended with concessional funding provided by a development partner. Venture capital investments in digital agriculture have increased in the past five years, with significant investments in precision agriculture, agriculture marketplaces, FinTech, AgTech imagery, and indoor agriculture.<sup>104</sup>



While much of the focus is on developed countries, particularly the United States, venture investment in developing countries has been increasing. The International Finance Corporation (IFC) of the World Bank has an important role to play in this space. IFC has a significant venture portfolio that it invests on commercial terms in emerging markets, including food systems. Examples include Chaldal in Bangladesh, an online grocery delivery service, and Big Basket in India, which has added groceries to its portfolio of products and is sourcing from farmers. IFC also invests indirectly through funds into companies, such as Agrofy in Argentina, which provides an online agriculture marketplace, and Agrostar in India, which is an online marketplace for agricultural inputs. Leveraging blended finance, IFC has also directly invested in early stage AgTech companies such as Kenya's Twiga Foods. Blended finance could potentially help provide financial support to high-development impact investments that would otherwise not easily attract financing on strictly commercial terms because risks are high and the returns are either unproven or not commensurate with the level of risk.

**Support increased use of digital payments, particularly for the poor and vulnerable groups.** Digital payments can be an important element of entrepreneur success. For example, digital payments through e-commerce platforms can help broaden an entrepreneur's client base and enable farmers to more easily sell or purchase products on these platforms. Expanding network coverage can help increase scope for digital payments. Poor network quality and coverage can lead to transaction failures that can

erode confidence and trust among users. Opening a bank or mobile money account usually requires some form of official government identification, such as an identification card, which many people in rural areas lack. Digital identification can help bridge this gap. Digital payment systems are only successful if there is sufficient interest and trust from both entrepreneur and customers to use this form of payment. An appropriate consumer protection framework, robust digital networks, and banking and telecoms policies that support digital financial services are all important components of a functioning digital payment system.<sup>105</sup> In addition, targeted efforts are needed to support inclusion of the poor and elderly in these payments systems to prevent widening inequality.<sup>106</sup> When digital applications require digital payments, the unenrolled get locked out.

**Support development of digital identification for farmers.** Digital identification provides a critical platform for digital agriculture service providers to scale their businesses because startups and digital agricultural solution providers spend about 50 percent of their initial business development efforts profiling and identifying target farmers. In addition, digital identification, especially when linked to land and livestock assets, is a powerful bridge for farmers to access financial services, to reduce fraud and improve efficiency in the delivery of goods and services, and for governments to better target agricultural support. For example, Estonia put 99 percent of its public services online and enabled online identity verification and authentication via a platform that connects various registries to the country's foundational digital ID system. As a result,

Estonia's farmers spend 45 minutes, on average, on support applications, down from 300 minutes using the previous paper-based system. They also receive their payments more rapidly as transfers are directly linked to their bank accounts. Furthermore, farmers can register land and cattle online and access detailed geographic and soil-related information through the platform. Another example is Uruguay, which has become a leading exporter of meat since implementing a livestock traceability system. The system setup was initially motivated by an outbreak of foot-and-mouth disease in 2000 and 2001, which led to the overhaul of a paper-based system that had been in place for 30 years. Each head of cattle is associated with an individual farmer, based on his or her national ID.

## Facilitate demand for digital technologies in the food system

**In the absence of demand for digital technologies, actions to facilitate supply are unlikely to increase adoption.** Digital technologies are not an end in themselves, but a means to help improve food system outcomes. If food consumers are not demanding more transparency, food distributors will have little incentive to adopt digital technologies to ensure traceability. If farmers retain their production for subsistence consumption, they will likely have little use for mobile phone-based systems that facilitate price discovery. If governments do not promote policies that involve payments to farmers, they will likely have little interest in technologies that allow more accurate targeting

of government-to-farmer payments. Where there is demand for better outcomes that digital technologies can help deliver, then several factors can boost demand for digital technologies, including: support for knowledge and skills development; ensuring development of relevant, customized digital tools in a suitable format and relevant languages; reducing the cost of adoption and facilitating access to finance if needed for adoption; and building trust in digital applications. Complementary infrastructure investments such as roads, energy, and post-harvest storage can help link farmers to markets that would make several digital technologies more relevant to them.

**Support farmer knowledge and skills, particularly those of poor farmers, women and other vulnerable groups.** There is a high correlation between digital adoption and basic skills. Investments to increase digital literacy and knowledge can help farmers take advantage of digital technologies.<sup>107</sup> Targeting support to poor farmers, especially women, can help reduce disparities in adoption. Larger scale, better educated, and wealthier farmers are better positioned to take advantage of digital technologies.<sup>108</sup> In addition, in low- and middle-income countries fewer women than men own a mobile phone or use the Internet.<sup>109</sup> Lack of digital literacy contributes to the gender gap in ICT usage.<sup>110,111</sup> Support to farmers that are at risk of exclusion from digital technologies could be provided through extension and advisory services, with various forms of learning having different impacts on rural women.<sup>112</sup> Agricultural extension systems can also take advantage of digital technologies to disseminate information and knowledge as discussed earlier in this paper. In addition,

public-private partnerships can help farmers gain a presence on e-commerce platforms. For example, technical support was provided to melon farmers in the Xinjiang Region in China to improve the quality of their produce, support online promotion, and manage logistics shipments to clients.

### **Develop relevant customized tools in a suitable format and relevant languages.**

For example, in Ghana, the Talking Book, a behavior change initiative, experienced high adoption rates by providing 140 hours of audio content about agriculture and other rural issues in local languages to illiterate people via a low-cost audio computer. From 2008 to 2015, the number of people who used Talking Books increased from 1,000 to 175,000 in Ghana alone. In 2012, the average harvest of a farmer that had used a Talking Book increased by 36 percent after one year.<sup>113</sup> In Rwanda, an e-wallet initiative for farmers experienced low uptake because SMS messages were sent in English rather than in Kinyarwanda.<sup>114</sup> To identify potential users' needs correctly it is crucial to include participatory approaches in digital agriculture initiatives.<sup>115</sup> A needs assessment conducted for the Kubere Centre in Uganda indicated that women were primarily interested in farming techniques, market prices for farmer produce, and health and education issues.<sup>116</sup> Consequently, this information was provided through radio and mobile phones used by women. Digital technologies can be designed to enable smallholder farmers with low cognitive skills to learn and upgrade their skills as they use them. This process encourages inclusion rather than displacement of low-skilled smallholders and helps raise their productivity.

### **Reduce the costs of digital technology adoption.**

The fees that farmers pay for digital services seem to influence adoption rates.<sup>117</sup> The public good nature of a particular digital service needs to be reflected in its price for farmers, particularly for women farmers. For example, if the objective of mobile-phone-based market information programs for poor rural areas is to improve equity, shouldn't this information be provided for free as a public service cost to government? These types of public subsidies should not displace private sector activity, but in areas of high poverty with low ability to pay, displacement may not be a concern. Another policy that can help reduce the cost of digital services is to lower the cost of expanding network coverage to rural areas, as noted earlier in the paper.

### **Improve access to financial services.**

Finance for agriculture through commercial banks remains limited; for example, about 1 percent of commercial credit in Africa goes to agriculture. Microfinance institutions in several countries do serve rural households but at a relatively high cost, and governments often step in through policies, regulations, and state financial institutions. Despite good intentions, some of these measures do not achieve the intended outcomes, and may instead hinder the sustainable provision of financial services for agriculture, while also failing to crowd-in private sector participation. In most countries, despite government intervention, agriculture attracts credit well below its contribution to GDP. Among key issues for preventing the spread of financial services in rural areas and agriculture are a high cost to serve clients in remote areas (with seasonal and small transactions), and perceptions of risk due to lack of agroclimatic data

and financial records. Digital technologies can help in providing solutions to both these issues. Digital financial services, through mobile phones, ATMs, Internet-banking, and agent banking, can reach smallholder farmers in remote areas at very low cost. In terms of risks, digital technologies can provide information on agroclimatic risks, enabling providers of financial services to assess the riskiness of production that their clients face. In addition, digital payments and other transactions that use digital platforms generate financial records that can help providers of financial services assess credit risks for these clients where other forms of financial records do not exist.

**Invest in complementary infrastructure and policies that increase incentives to invest.** Lack of complementary rural infrastructure, such as roads, energy, post-harvest storage, and logistics can limit adoption and impact of digital technologies in agri-

culture.<sup>118</sup> For instance, it is difficult to sell products on e-commerce platforms if there are no roads to markets, or to sell high-quality fruits to online customers if there is no storage to preserve their freshness for distant markets. A recent study in China indicated that poor storage and transportation, particularly for perishable products, was a factor in decisions not to sell products online.<sup>119</sup> In addition, rural electrification can help facilitate rural-based food processing and value addition. Some of these sectors (roads, electrification, and storage) may be able to crowd-in private investment, and could be the subject of their own “cascade” considerations of public-private investment (see table 1) but that is beyond the scope of this paper. In addition, there are also significant policy improvements countries can make to increase incentives of farmers and agribusinesses to invest in farms and across agricultural value chains,<sup>120</sup> which, in turn, can increase demand for digital technologies.







## Implementation considerations

Implementation using an MFD approach requires a more private sector-oriented perspective and public-private dialogue informed by ex-ante analytics and data on constraints and opportunities<sup>121</sup> to enhance digital technologies to improve food system outcomes. This approach can help guide the prioritization of public sector actions, particularly on efficiency, equity, and environmental impacts, and to address risks associated with digital technologies such as potential exclusion, lack of data privacy, market concentration of service providers, and cybersecurity breaches. Targeting public support and efforts to improve data privacy are two aspects worth reiterating.

- **Targeting public support to foster digital inclusion in the food system should be a key consideration, with particular attention to disadvantaged groups.** This process includes: expanding network coverage

to more remote rural areas; supporting youth and women entrepreneurs with mentoring and technical support; improving the skills of smallholder farmers to better take advantage of digital technologies; and fostering development of digital technologies, including government e-services, customized to the needs and general skills levels of farmers, delivered in suitable formats and relevant languages. Women are particularly disadvantaged as regards access to, use and control of digital tools, especially in developing countries.<sup>122</sup> Programs can be designed to have significant impacts on women. For example, recent support connected women farmers with agricultural market platforms in Bihar, India. The project organized women farmers into their own producer company and supported them with a host of services: daily commodity price information via mobile phones; digital scales and

electronic moisture meters to challenge manipulated equipment of traders; access to an online commodity exchange allowing them to sell anywhere in the country; and improved access to storage and warehousing so they could delay selling until prices improved. These interventions resulted in a 20 percent increase in the product prices the women farmers received. Beyond individual programs, digital innovations should be mainstreamed into national strategies in a gender-sensitive way to help advance the processes of women's social inclusion. There is also a need to collect gender-disaggregated data to analyze how women and men access digital tools and use them for agriculture-related activities, and how access for women can be improved.

- **Data privacy considerations.** Efforts to improving data privacy should give consideration to three underlying principles: (i) transparency in data collection, in other words, individuals should know if someone is collecting their data; (ii) individuals need to know and have a voice in how their data are being used; and (iii) data sharing models need to work for both data suppliers (individuals) and users (enterprises/companies). Data governance arrangements should serve to build confidence and trust of users of digital technologies, such as farmers and agribusinesses, and help facilitate development of digital applications that can benefit these farmers and agribusinesses, such as improving access to finance, as discussed earlier in the paper.

### **Multi-agency and multisectoral collaboration, and the role of ministries of agri-**

**culture.** While implementation will require collaboration and action across government ministries—including communication, finance, education, rural development, and transportation—agriculture ministries need to play a more prominent role in enhancing digital technologies to improve food system outcomes. To achieve this, agriculture ministries need to: (i) engage with the private sector to develop a clear and mutual understanding of constraints and opportunities to enhancing digital technologies in the food system; (ii) engage with other ministries and provide a voice to policies and investments needed in the food system such as digital and other infrastructure, investment climate, digital skills development, and entrepreneurship programs, as well as facilitate government-to-government data sharing and linkages; (iii) provide direct support through e-extension to farmers, digital skills development programs, market information services, matching grants for facilitating digital entrepreneurship, and programs to support women farmers, such as the Bihar example cited above; and (iv) digitize some of their own systems including government-to-farmer payments (e-vouchers), early warning and risk management systems, and M&E.

**Countries need to tailor actions to specific local conditions.** Prioritizing actions across supply-side constraints (such as a lack of network coverage and limited digital content), and demand-side constraints (such as lack of knowledge or complementary investments) will obviously depend on which of these aspects is most pressing in a specific location. For example, some countries have lower digital applications per person than their network coverage would seem

to suggest, based on cross-country comparisons, indicating perhaps that relatively more attention should be given to entrepreneurship to develop digital applications and content in these cases, especially for smallholders. While other countries have higher digital applications per person than their network coverage would seem to suggest, indicating perhaps relatively more attention should be given to expanding network coverage relative to entrepreneurship.

Digital technologies have the potential to transform the food system through better informed and engaged consumers, smarter farms, and improved delivery of public services. Digital technologies also pose several risks, including exclusion, lack of data privacy, cybersecurity breaches, and over-concentration of service provider market power. Addressing these risks calls for public policies that: keep service provider entry barriers low; ensure good data governance; foster inclusion through targeted support

to smallholder farmers, youth, women, and other vulnerable groups; and support skills development and training. Public policy should also focus on creating an enabling environment that will create effective demand for digital technologies that deliver improved food system outcomes. Through monitoring uptake of these technologies, public actions can focus on resolving bottlenecks that prevent the market from responding to demand, such as: investing in digital entrepreneurship, human capital development, and supporting infrastructure; encouraging private sector competition to improve the availability of digital technologies and lower costs of adoption; regulating the use of digital technologies to reduce potentially harmful uses; and in some cases, subsidizing the use of digital technologies by disadvantaged groups to ensure that they do not fall even further behind. These actions can all harness digital technologies to provide much-needed improvements in food system outcomes.









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