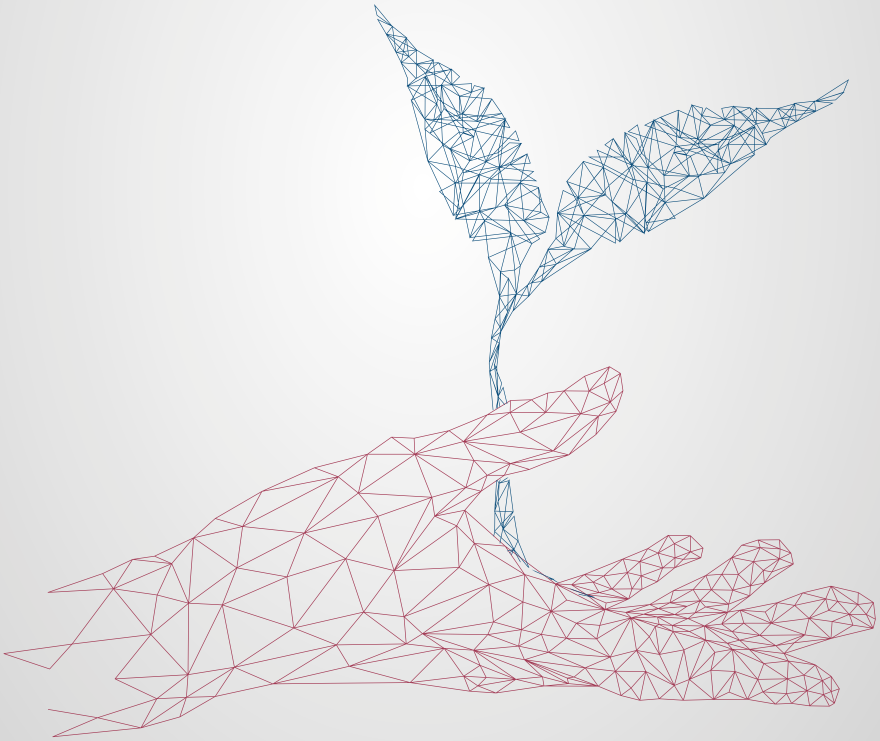
Food and Agriculture Organization of the United Nations

DIGITAL TECHNOLOGIES
IN AGRICULTURE AND RURAL AREAS
BRIEFING PAPER




N
K
P

DIGITAL TECHNOLOGIES
IN AGRICULTURE AND RURAL AREAS
BRIEFING PAPER

by
Nikola M. Trendov, Samuel Varas, and Meng Zeng

Food and Agriculture Organization of the United Nations
Rome, 2019

CONTENTS

Figures

1 INTRODUCTION AND BACKGROUND

The agriculture and food sector is facing multiple challenges. With the global population projected to grow from 7.6 billion in 2018 (UN DESA, 2019) to over 9.6 billion in 2050 there will be a significant increase in the demand for food (UN DESA, 2017). At the same time, the availability of natural resources such as fresh water and productive arable land is becoming increasingly constrained.

Production is not the only concern; although agricultural output is currently enough to feed the world, 821 million people still suffer from hunger (FAO, 2018). Processes such as the rapid rate of urbanization are also having important implications for patterns of food production and consumption.

The agrifood sector remains critical for livelihoods and employment. There are more than 570 million smallholder farms worldwide (Lowder et al., 2016) and agriculture and food production accounts for 28% of the entire global workforce (ILOSTAT, 2019).

Achieving the UN Sustainable Development Goal of a 'world with zero hunger' by 2030 will require more productive, efficient, sustainable, inclusive, transparent and resilient food systems (FAO, 2017b p. 140). This will require an urgent transformation of the current agrifood system.

Digital innovations and technologies may be part of the solution. The so-called 'Fourth Industrial Revolution' (Industry 4.0)[1] is seeing several sectors rapidly transformed by 'disruptive' digital technologies such as Blockchain, Internet of Things, Artificial Intelligence and Immerse Reality. In the agriculture and food sector, the spread of mobile technologies, remote-sensing services and distributed computing are already improving smallholders' access to information, inputs, market, finance and training. Digital technologies are creating new opportunities to integrate smallholders in a digitally-driven agrifood system (USAID, 2018).

The next period of growth in mobile connections is expected to come mainly from rural communities. Already, 70% of the poorest 20% in developing countries have access to mobile phones (World Bank, 2016). Additionally, more than 40% of the global population has internet access and there are major initiatives to connect those in rural areas of developing countries (World Bank, 2016).

However, there are challenges to consider in the 'digitalization' of agriculture and food value chain. The transformation must be done carefully in order to avoid an increase of a 'digital divide' between economies and sectors and between those with differing abilities to adopt new technologies (OECD, nd). In emerging economies and rural areas, weak technological infrastructure, high costs of technology, low levels of e-literacy and digital skills, weak regulatory framework and limited access to services mean these areas risk being left behind in the digitalization process.

Yet, developing economies may also have the advantage of being able to 'leapfrog' older agrifood technologies and models in favour of a digital agriculture revolution. This new scenario will require radical rethinking by policy makers, international organizations, business leaders and individuals: 'business as usual' is not the solution.

1.1 The digital agriculture revolution

Historically, agriculture has undergone a series of revolutions that have driven efficiency, yield and profitability to previously unattainable levels. Market forecasts for the next decade suggest a 'digital agricultural revolution' will be the newest shift which could help ensure agriculture meets the needs of the global population into the future.

1 The term Industry 4.0 originated in Germany where it was applied to rapid transformations in the design, manufacture, operation and service of manufacturing systems and products (European Parliament, 2015a)

Digitalization will change every part of the agrifood chain. Management of resources throughout the system can become highly optimized, individualized, intelligent and anticipatory. It will function in real time in a hyper-connected way, driven by data. Value chains will become traceable and coordinated at the most detailed level whilst different fields, crops and animals can be accurately managed to their own optimal prescriptions. Digital agriculture will create systems that are highly productive, anticipatory and adaptable to changes such as those caused by climate change. This, in turn, could lead to greater food security, profitability and sustainability.

In the context of the Sustainable Development Goals, digital agriculture has the potential to deliver economic benefits through increased agricultural productivity, cost efficiency and market opportunities, social and cultural benefits through increased communication and inclusivity and environmental benefits through optimized resource use as well as adaptation to climate change.

The potential benefits of digitalizing the agrifood sector are convincing but it will require major transformations of farming systems, rural economies, communities and natural resource management. This will be a challenge and requires a systematic and holistic approach to achieve the full potential benefits.

1.2 Digital divide

Digitalization of the agrifood system involves the risk that the potential benefits will be unequally distributed between rural and urban areas, gender, youth population. Urban areas often have better developed 'digital ecosystems' (resources, skills, networks) compared with rural areas. Combined with global trends of urbanization and middle and rich classes settling in cities, there is potential for digitalization to exacerbate existing rural-urban disparities (UN DESA, 2018a) and populations to fall behind in the process of a digital transformation. FAO is committed to assist governments and partners bridging such multidisciplinary digital divides to ensure that everyone benefits from the emerging digital society.

1.3 Conditions for a digital transformation

There are several conditions that will shape the digital transformation of agriculture in different contexts:

- Basic conditions are the minimum conditions required to use technology and include: availability, connectivity, affordability, ICT in education and supportive policies and programmes (e-government) for digital strategies;

- Enabling conditions ('enablers') are factors that further facilitate the adoption of technologies: use of internet, mobile phones and social media, digital skills and support for agripreneurial and innovation culture (talent development, sprint programmes including hackathons, incubators and accelerator programmes).

2 BASIC CONDITIONS FOR DIGITAL TRANSFORMATION

There are some basic conditions that must exist for the use of digital technologies and therefore for digital transformation of the agriculture and food sector. These include: infrastructure and connectivity (mobile subscriptions, network coverage, internet access, and electricity supply), affordability, educational attainment (literacy, ICT education) and institutional support.

Access to digital technology can offer significant advantages to smallholder farmers and other rural business by providing links to suppliers and information and allowing users to tap into workforce talent, build strategic partnership, access support services such as training, finance and legal services and, critically, reach markets and customers.

However, the introduction of digital technologies in rural areas can be a challenge. Around the world, rural populations are declining and education and employment opportunities are limited. There is often a lack of infrastructure, including basic IT infrastructure, particularly in very remote rural communities and those with large indigenous populations. The costs associated with IT infrastructure present a major challenge in rural areas where rates of poverty are often high, especially in developing countries and least-developed countries (LDCs).

2.1 IT infrastructure and networks in rural areas

In the era of digitalization, Information and Communication Technologies (ICT) such as mobile phones and computers have revolutionized how people access knowledge and information, do business and use services. Yet there remain significant digital divides both within and between countries (European Parliament, 2015b).

2.1.1 CHALLENGES

Globally, mobile cellular subscriptions have been growing over recent years. Between 2013 and 2018 there were 1 billion new mobile subscribers and 67% of the world population is now subscribed to mobile services (GSMA, 2018c; 2019a). Much of this recent growth has been driven by countries in Africa and Asia and the Pacific. Access to computers and internet has also been increasing in LDCs and developing economies. Yet 3.8 billion people still remain offline and are disproportionately located in rural and remote areas (GSMA, 2018c).

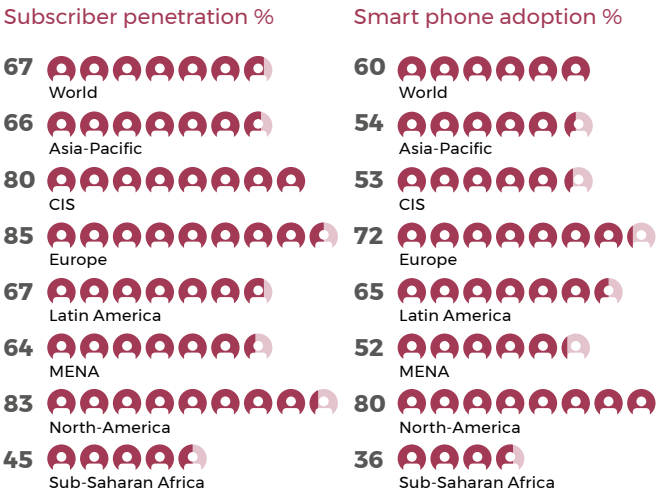
One challenge is that network coverage in rural areas remains limited. Despite 4G becoming the most common mobile connection globally and 90% of being able to access the internet through 3G or higher quality network, only around a third of rural populations in LDCs receive coverage by 3G networks (GSMA, 2019a).

Smartphones have become a major way for consumers to access internet. Falling handset prices and innovations such as pay-as-you-go plans mean that mobile devices are increasingly affordable and accessible, including for rural communities (Hahn and Kibora, 2008). Among the world's poorest households, 7 out of 10 have a mobile phone and more households in LDCs (ITU, 2018). However, these are not always web-enabled smartphones.

Although the growth of smartphone ownership and use of mobile broadband has been faster in developing countries than developed countries in recent years, there are still twice as many mobile-broadband subscriptions per 100 inhabitants in developed countries as in developing countries (Figure 1). Affordability is the main barrier to smartphone ownership in LDCs where a basic mobile broadband plan still corresponds to over 60% of gross national income per capita on average (ITU, 2017).

Figure 1 Subscriber penetration and smartphone adoption (%) by region, 2018.

Source: GSMA, 2019a.



2.2 Educational attainment, digital literacy and employment in rural areas

The use of digital technologies requires basic literacy and numeracy as well as special technical knowledge and skills. People without such competencies can end up marginalized in increasingly digitally driven societies.

2.2.1 CHALLENGES

In rural areas, a lack of infrastructure and resources often limits the quality of education. This leads to less effective learning, lower attendance rates and early school leaving. Additionally, in many rural areas, youth are often required to work which leaves little time for school.

Rates of educational attainment are therefore often lower in rural areas than urban areas, especially in LDCs (see Figure 2). Despite the fact that 60% of the countries for which data are available have eradicated or nearly eradicated youth illiteracy, literacy remains low in many rural areas of LDCs and particularly among women (UNESCO, 2017). A lack of basic literacy and numeracy presents a significant barrier to using digital technologies.

In addition, 'digital literacy' is critical for using digital technologies. Unlike in many developed countries, where students regularly use advanced technologies and digital skills in their education and day-to-day lives, ICT knowledge and skills lag behind in LDCs. In many LDCs and developing countries, basic computer courses are not integrated in primary or secondary education due to a lack of interest from governments and the private sector to invest in building new digital skills rather than hiring already skilled labour.

A lack of digital tools, such as tablets and laptops, in schools is identified by teachers as a major obstacle to IT education (European Commission, 2019). There is also a lack of relevant skills among teachers. This tends to be particularly true in rural areas. For schools in urban areas, access to the internet and online learning resources is usually commonplace. However, rural and remote schools often lack access to internet. This pattern is true even in developed countries, but is particularly pronounced in developing countries and LDCs.

Over the next 15 years, around 1.6 billion people in developing countries and LDCs will reach working age. Creating the necessary jobs while sustaining existing employment will be a significant challenge, especially for the agrifood sector (World Bank, 2017). Rural unemployment is particularly high and disproportionately affects youth and women. The agricultural sector remains a major source of livelihoods in rural areas. Digitalization of the sector will significantly alter the nature of work and the demand for labour and skills. Increasingly, digital literacy will be a requirement in agrifood jobs and suitable education and training will be required.

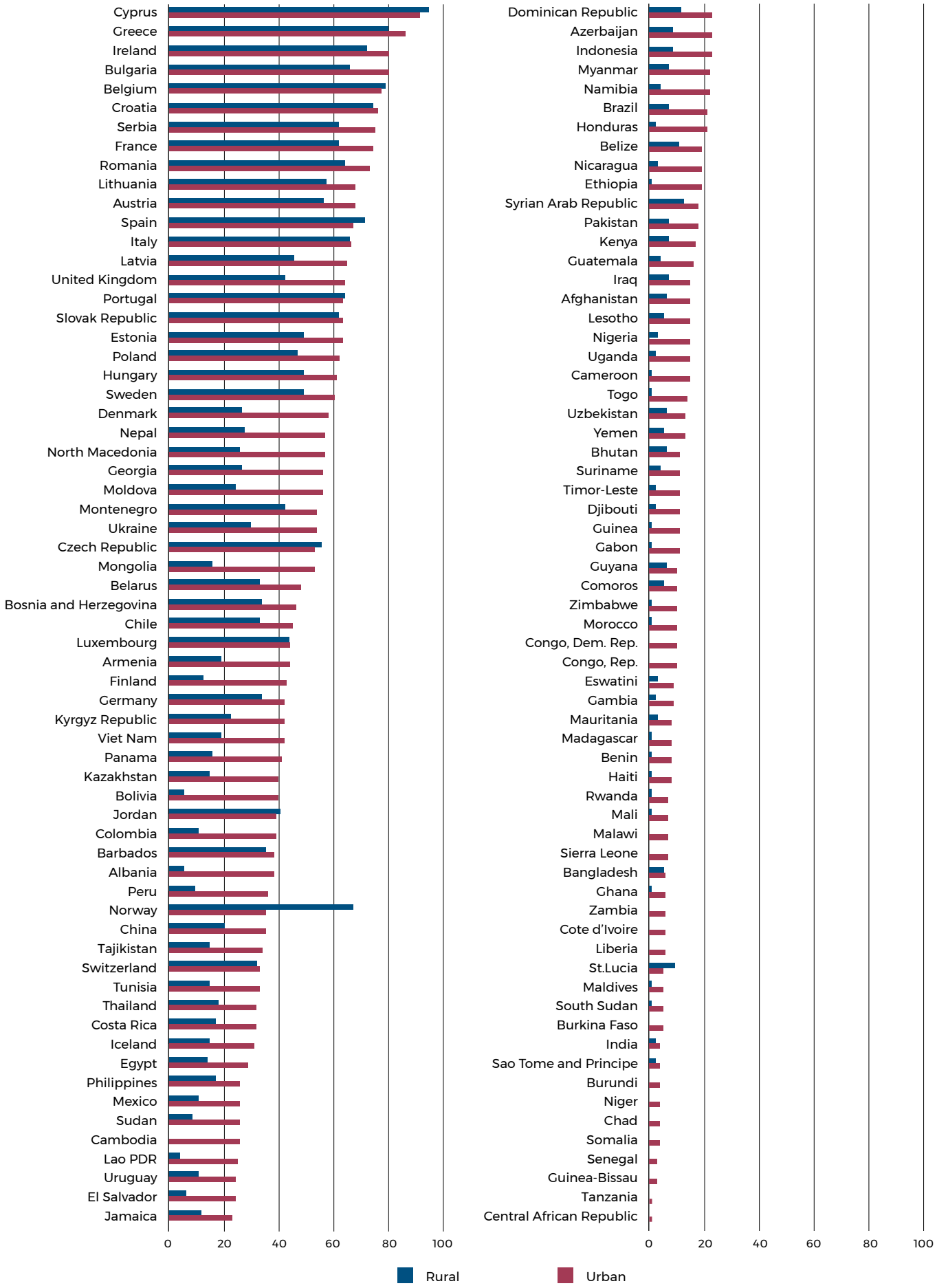
2.3 Policies and programmes for enabling digital agriculture

In many countries, government policies and frameworks are one of the driving forces behind digitalization. These create an enabling environment for competitive digital markets and e-services. There is also a trend towards governments themselves deploying e-services – 'e-government' – especially in health, education, environment, and employment.

However, designing and managing a digital government program requires a high level of administrative capacity and as a result some countries have had limited success (Fakhoury, 2018). Developing countries are often the ones with the least capacity to manage the process. Success also varies by sector and, in many countries, the agricultural sector – a major employer in rural areas – lags behind.

There is a lack of published research on government digitalization policies, but information can be inferred from proxies including the extent to which governments provide e-services and their policies regarding connectivity and data.

Figure 2. Higher education attendance by degree of urbanization.
Source: UNESCO Institute for Statistics, 2018.



2.3.1 CHALLENGES

Compared with just a decade ago, governments have made significant progress in expanding ICT access and digital networks. Some developed countries are reaching near universal access through fixed and mobile connections whilst progress is being made in developing countries through the expansion of mobile services.

Many governments have begun using e-services in sectors such as health and education (Figure 3). However, in LDCs and developing countries, many people cannot use e-services because they lack access to ICT due to low incomes, limited user capabilities and a lack of infrastructure (McKinsey & Co, 2014). As the pace of technological innovation intensifies, this is likely to limit further development of e-government in these countries.

The type of licensing framework and efficiency of spectrum allocation[2] that governments use can be important in encouraging the private sector to invest in mobile networks in remote areas. The experience of EU countries suggests that greater liberalization of the telecommunications sector supports widespread connectivity. Efficient spectrum management can also favour mobile network operators through lower deployment costs which will bring to end user in terms of greater access to ICT services.

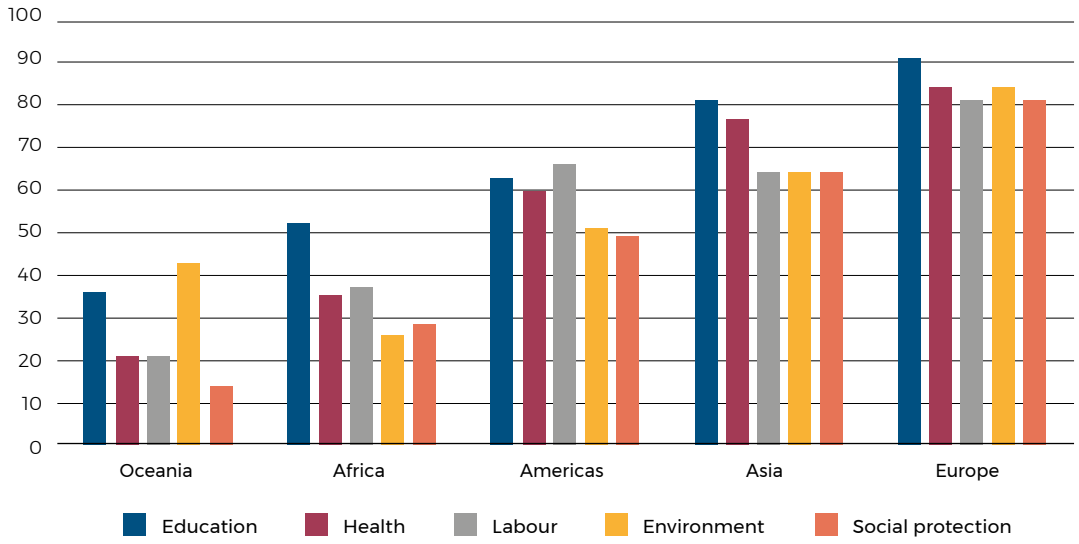
Development of government e-services has often been particularly slow in the agricultural sector and few countries provide e-Agriculture services. Those countries that do prioritize the use of ICT in agriculture also generally have a better business environment and policy and regulation framework for agribusiness. It is possible this is linked to the use of ICT as it does not seem to be related to levels of education, literacy or agricultural contribution to GDP in a country.

So far, developed countries are leading on implementing national level strategies on digital agriculture. In some cases, this is by integrating the agrifood sector as a key focus within existing national digital strategies that aim to transform wider industry and society. In developing countries, most of the e-Agriculture services are embedded within e-government or ICT strategies where the main objective is to provide basic e-Agriculture services such as early alert notifications and general information.

The use of digital technologies will create the need for policy and regulation in relation to the data that will be generated. A lack of standardization in the format and ownership of data could create disparities, particularly in a scenario where large international companies are pursuing digital agriculture for agribusiness whilst smallholders and local agripreneurs are simultaneously using technologies to tackle societal challenges in rural and farming areas.

Figure 3. Governmental services provided via email, Short Message Service (SMS) or Really Simple Syndication (RSS) (% of countries in each region), 2018.

Source: UN DESA, 2018



2 Spectrum allocation refers to the radio frequencies allocated to the mobile industry and other sectors for communication over the airwaves (GSMA, 2019b)

3 ENABLERS FOR DIGITAL AGRICULTURE TRANSFORMATION

In addition to basic conditions, there are important enablers that facilitate digital agricultural transformation. Three key enablers are: the use of internet and mobile and social networks among farmers and agricultural extension officers, digital skills among the rural population and a culture which encourages digital agripreneurship and innovation.

With the rise of high speed internet connections and web-enabled smartphones, mobile apps, social media, VoIP[3] and digital engagement platforms have significant potential to improve access to information and services for those in rural areas. However, many small-scale farmers in developing countries remain isolated from digital technologies and lack the skills to use them.

Establishing a 'digital agriculture ecosystem' requires an enabling environment for innovation by farmers and agripreneurs. Already, there is increasing funding and collaboration on digital agriculture projects and start-ups are beginning to attract international investors and media attention. Youth have a particular role to play in this process. They often have the advantage of digital literacy and the capacity for innovative solutions. When digital topics are integrated in educational programs they can also gain an understanding of the uses of digital tools and the skills to create them.

3.1 Use of digital technologies among rural populations and farmers

Literacy and digital skills and the availability of technologies all affect the use of digital innovations.

However, the most critical component for unlocking the possibilities of digital technologies use is access to the internet.

Although almost half of the world's population is now using the internet, this is disproportionately in developed nations. In LDCs, only one out of seven people uses the internet (ITU, 2016) and there are apparent disparities between rural and urban areas (although the patterns vary between countries).

Education and income levels are strong determinants of how (and if) people use the internet. Those with higher levels of education tend to use more advanced services, such as e-commerce and online financial and governmental services. Users with lower education levels tend to use the internet predominantly for communication and entertainment.

In rural areas, where education and literacy rates are generally lower, mobile phones tend to be used mainly for communication and social media. This presents a challenge for the introduction of digital agriculture applications which require more advanced digital skills.

Low overall smartphone ownership in rural areas combined with the high cost of internet and limited network coverage also present challenges to the use of mobile agricultural applications and limit the scope to use social networks like Facebook to facilitate agricultural support and information flows between farmers. Such availability of information could support farmers to make better farming decisions which could contribute to increasing yields, reduced environmental impacts and improved livelihoods.

The diversity of available technologies and the lack of standardisation and compatibility between them, for

3 Voice over Internet Platforms or phone services over the internet

example for the exchange of data, also create a barrier to use by farmers. The adaptability of technologies is limited and it is often not possible to integrate machinery from different brands so farmers must decide which brand to invest in. There is a lack of independent advisory services to support farmers in making these decisions.

3.2 Digital skills among rural populations

Digitalization creates demand for digital skills and for people who are competent in using digital devices, understanding outputs and developing programmes and applications. This requires not only basic literacy and numeracy but also data handling and communication skills. In populations where such skills are lacking, education must improve quickly; ICT is developing at an incredibly rapid pace and rates of learning must keep up (UNDP, 2015).

Alongside investment in technology, there is therefore a growing need for investment in the development of multidisciplinary digital skills and knowledge. This is true in both developed and developing countries. Countries that have ICT education programmes, can afford digital tools and have good access to the internet will have better digital skills.

In the agrifood sector, the digital transformation will change the structure of the labour market and the nature of work. It will redefine the role of farmers and agripreneurs and alter the skill set required in the agrifood sector. It may also transform how and where people work and is likely to affect female and male workers differently due to differences in digital skills and technology use. Rural areas in particular lag behind in the process of gaining digital skills (Figure 4). There is a need to develop a model of digital skills training aimed at farmers so they can learn to assess and implement the best practices and technologies for their farm business.

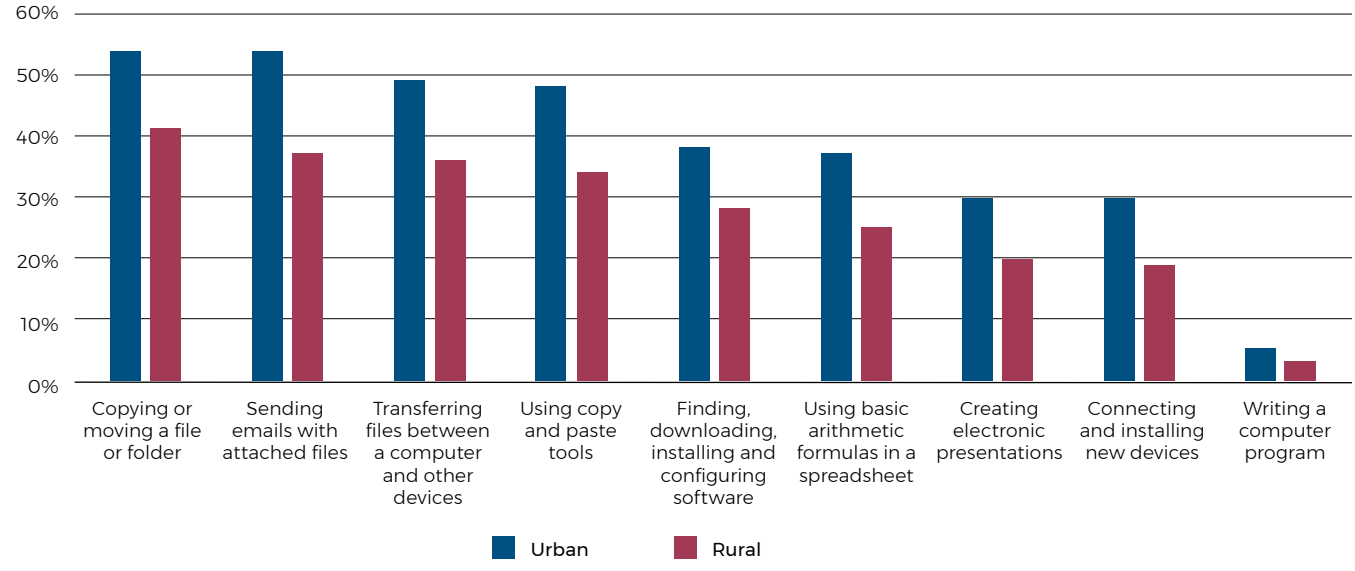
3.3 Digital agripreneurial and innovation culture

Digital entrepreneurship involves the transformation of existing businesses through novel digital technologies and the creation of new innovative enterprises characterized by: the use of digital technologies to improve business operations, the invention of new (digital) business models and engaging with customers and stakeholders through new (digital) channels (European Commission, 2013). Globally, there are an increasing number of initiatives to foster digital entrepreneurial activity related to the creation, development and scaling-up of 'digital start-ups', including in the agriculture and food sector.

Modern day farmers may be particularly suited to entrepreneurial activities. These days, farmers often design business plans, scout for funding, make use of farming enterprise 'incubators' and attend scientific conferences. Youth farmers in particular are also more likely to take risks in their farm management. In Italy, for example, over 12 000 agricultural start-ups were created in 2013 by men and women aged 25 to 30 (Coldiretti, 2018).

Developed countries are so far the leaders in establishing an entrepreneurial culture, but less developed countries

Figure 4. Average proportion of the population in rural and urban areas with a specific digital skill, 2017.
Source: ITU, 2018.



such as Rwanda, Zambia, Turkey and Armenia are also rapidly pursuing these opportunities in the digital age.

3.3.1 CHALLENGES

Entrepreneurship presents a promising option for development and business in rural communities.

With its large farming sector and consumer market, Africa is anticipated to be a major testing ground for digital solutions by agritech groups (Figure 5). At the beginning of 2018, there were 82 agritech start-ups operating across Africa with over half launching in the previous two years (Disrupt Africa, 2018).

However, despite the rapid growth of digital agricultural technologies, most ICT-enabled solutions have yet to be demonstrated at scale. Companies – especially SMEs and small start-ups – often struggle to move from the stage of application development to fully realized businesses. One challenge is that there is a lack of guidance for entrepreneurs on scaling strategies in under-served markets.

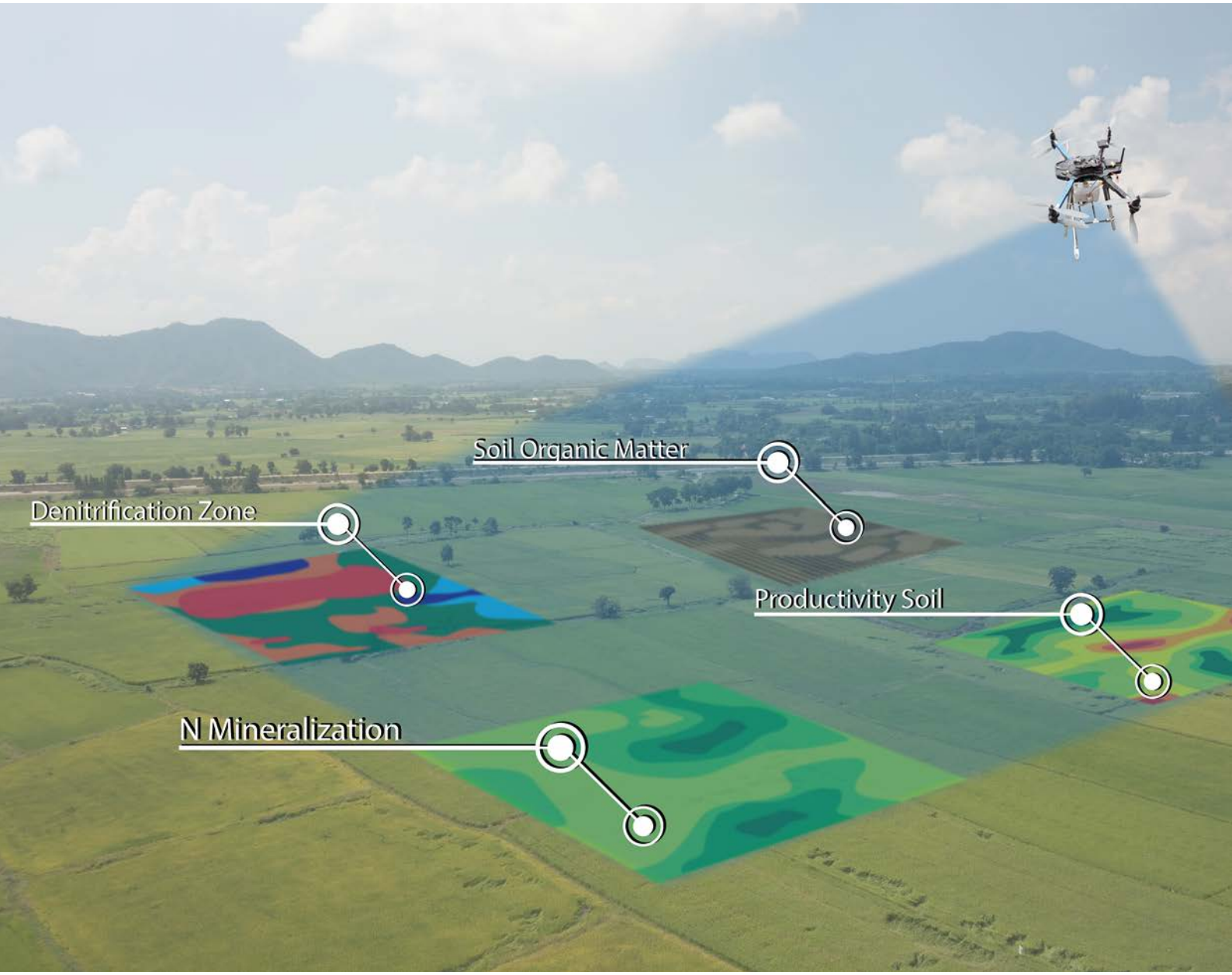
To encourage digital agripreneurship, companies need to create pools of digitally-skilled employees. This involves finding potential employees with relevant skills and identifying how they can be attracted and retained, as well as recognizing talent that can be nurtured within the existing employee base and investing in developing digital skills in existing roles.

Education is the most critical factor to accelerating innovation and digital transformation. Governments need to adopt a three-pronged approach to stimulating research and development (R&D) and innovation education: investing in R&D, amplifying indigenous R&D and working with a broad coalition of partners to redesign education to emphasize e-learning tools, do-it-yourself hands-on learning, rewards for experimentation, critical thinking, and digital and financial literacy and software skills.

Youth agripreneurs have a key role to play in the digitalization of the agricultural sector. They have unique insights from listening to the experiences of their parents and grandparents and observing missed opportunities. Start-ups from smallholder farming communities often draw inspiration from, and are aimed at helping, the farming communities where the creators grew up. Youth will need sprint programmes and financial support to penetrate the agripreneur market. Such programmes attract investment and create opportunities for investors and start-ups to form collaborations.

The existence of an entrepreneurial culture is often not related to the GDP or location of a country. The accessibility of e-commerce and digital platforms is making it increasingly easy for it to develop anywhere. Nevertheless, creating a sustainable digital agripreneurial culture is a long-term political and practical process, starting with appropriate education in schools. It requires an enabling environment which allows risk-taking, trust-based relationships between stakeholders, financial opportunities, professional services, a sustainable digital ecosystem[4], the availability of appropriate skills and an attitude of sharing or 'open innovation'.

4 A digital ecosystem is an interdependent collection of enterprises, people and/or things that share standardised digital platforms


Soil Organic Matter
Denitrification Zone
Productivity Soil
N Mineralization

4 EXAMPLES AND IMPACT OF THE USE OF DIGITAL TECHNOLOGIES IN AGRIFOOD SYSTEMS

Digital transformation has the potential to deliver significant economic, social and environmental benefits. The following examples demonstrate how digital technologies can be applied to improve the efficiency and functioning of agrifood systems:

- The use of mobile applications providing price information to farmers can reduce market distortions and help farmers to plan production processes. For example, the M-Farm application in Kenya led to farmers changing their cropping patterns and some reported receiving higher prices at market as a result (Baumüller, 2015);

EMA-I APP ANIMAL HEALTH SYSTEM SUPPORT BY FAO

EMA-i is an early warning app developed by FAO to facilitate quality and real time livestock disease reporting captured by animal health workers in the field. EMA-i is integrated in the FAO's Global Animal Disease Information System (EMPRES-i) where data are safely stored and used by countries. EMA-i is easily adaptable to countries existing livestock disease reporting system. By supporting surveillance and real time reporting capacities at country level and improving communication between stakeholders, EMA-i contributes to enhance early warning and response to animal disease occurrence with high impact to food security and livelihood. EMA-i is currently used in six countries in Africa (Cote d'Ivoire, Ghana, Guinea, Lesotho, Tanzania and Zimbabwe).

- Agricultural robots ('agrobots') are seen as a key trend that will deeply influence agriculture in the future. Field agrobots are already being deployed to help farmers measure, map and optimize water and irrigation use. Fleets of small lightweight robots are now seen as a replacement for traditional high mass tractors, allowing a gradual reduction of compaction, re-aeration of the soil and benefits to soil function;

DINO AGROBOT FOR AGRICULTURE AND VITICULTURE

The Naïo Technologies team developed agricultural robot to improve working conditions and profitability for farmers.

To help farmers tackle the increasing regulations on phytosanitary products, the growing concerns with pesticides, and the lack of workers in the agricultural sector, Dino provides a new and effective solution. The Dino weeding robot allows vegetable farmers to manage crop weeding with a high level of precision, while helping them save time all through the season.

Dino is highly effective to weed vegetables that are grown in the field, both in raised vegetable beds and in rows, such as lettuce, carrots, onions, etc.

https://www.naio-technologies.com/en/agricultural-equipment/large-scale-vegetable-weeding-robot/

- Technologies can also support farmers to anticipate and respond to pest attacks, crop failures and climatic changes through timely weather-based agro-advisory messages;

- Precision Agriculture (PA) is an example of an application of the Internet of Things (IoT) in agriculture. The use of Guidance Systems during planting and fertilizer application can lead to cost savings in terms of seed, fertilizer and tractor fuel, and can reduce working hours in the field. Variable Rate Technologies (VRT) and drones (UAV) can also reduce water and pesticide use and reduce labour and resource costs;

- The importance of ERP software in agriculture is high, as it has the potential to help streamline every process, from procurement to production to and distribution. ERP can enable a farm (or related business) to respond more organically to environmental challenges, adjust systems accordingly, and grow into a more cost-efficient businesses;

MYCROP COMPLETE FARM AND FARMER MANAGEMENT SYSTEM

MyCrop a technology-enabled initiative for farmers, which empowers them through delivering information, expertise and resources, to increase productivity and profitability, hence improving standard of living. It is a collaborative platform that strives to combine cutting edge technology (Big Data, machine learning, smartphones/tablets, etc.), innovative business model (agriculture platform as a service), and focused human efforts (agriculture insights, products, and services) to serve smallholder farmers.

MyCrop facilitates farmers in taking and executing optimum decisions by providing geo-mapping, crop planning, individual farm plans and farm automation customized for each farmer based on weather, soil, pest and crop data on an almost real-time basis.

MyCrop is a sustainable data-driven, scalable, intelligent, self-learning, real-time collaborative Agrifood system, which serves as a farm as well as farmer management solution, predictive analytics and monitoring tool, decision support system and agriculture (buy/sales side) e-commerce platform.

http://www.mycrop.tech

- Over the last few years, the growth in Artificial Intelligence technology (AI) has strengthened agro-based businesses to run more efficiently. Companies that use AI helps farmers to scan their fields and monitor every stage of the production cycle. AI technology is transforming the agricultural sector, as farmers can depend on the data that satellite or UAV record to determine the state of the farm rather than walking all the distance. AI can improve resource use, support early decision making through predictive models and maintain 24/7 monitoring systems;

ALIBABA GROUP HOLDING AND JD.COM LAUNCHES SMART BRAIN FOR PIG FARMS

Alibaba's "ET Agricultural Brain" is an AI programme that uses facial, temperature and voice recognition to assess each pig's health. The technology can tell whether a sow is pregnant by following its sleeping and standing positions as well as eating habits, and has been already adopted by a number of leading pig farms in China. With AI they are able to detect sick hogs and minimize accidents, such as protecting piglets from accidents through the introduction of voice recognition technology. Multiple meters are installed to collect data to optimize the environment for the herd to grow, as well as reducing human errors in the farming process.

Using AI, pig farms will reduce pig farmers' labour costs in the range of 30 percent to 50 percent, and lower the need for feed, as well as shorten hogs' lifespan by five to eight days by optimizing animals' growth conditions, based on the firm's estimate. China could save CNY50 billion (US$7.5 billion) if it applied the system to all pig farms nationwide.

https://www.yicaiglobal.com/news/chinese-aging-farms-step-into-ai-era-with-facial-recognition-for-pigs-

- Technologies such as Blockchain have also been shown to deliver benefits. For example, Blockchain has been successfully used to detect poor quality food in food chains allowing early and effective responses. It can also provide consumers with information on the origin of their food, generating a competitive advantage for those who use it.

WALMART TRACKS ITS LETTUCE FROM FARM TO BLOCKCHAIN

After a two-year pilot project, the retailer is using blockchain to keep track of every bag of spinach and head of lettuce. The giant retailer begin requiring lettuce and spinach suppliers to contribute to a blockchain database that can rapidly pinpoint contamination.

More than 100 farms that supply Walmart with leafy green vegetables will be required to input detailed information about their food into a blockchain database developed by IBM for Walmart and several other retailers exploring similar moves.

For Walmart, the initiative fits squarely into two key strategies: bolstering its digital savvy and emphasizing the quality of its fresh food to customers. The blockchain could also save Walmart money. When another food-borne illness hits — like the *E. coli* outbreak affecting romaine — the retailer would only have to discard the food that was actually at risk.

https://www.nytimes.com/2018/09/24/business/walmart-blockchain-lettuce.html

These technologies often require significant financial resources, large farm sizes and close integration with other technologies and agrifood chain processes. It is therefore a greater challenge for small-scale farmers to adopt such technologies, whereas as larger farmers and agribusiness companies will be more easily able to implement them.

5 CONCLUSIONS AND FUTURE WORK

The digitalization of agriculture will cause a significant shift in farming and food production over the coming years. Potential environmental, economic and social benefits are significant, but there are also associated challenges. Disparities in access to digital technologies and services mean there is a risk of a digital divide. Smallholder famers and others in rural areas are particularly at risk of being left behind, not only in terms of e-literacy and access to digital resources but also in terms of productivity and aspects of economic and social integration.

Simply introducing technologies is not enough to generate results. Social, economic and policy systems will need to provide the basic conditions and enablers for digital transformation. The "Law of Disruption" (Downes, 2009) states that technology changes exponentially, but economic and social systems change progressively and have trouble keeping up. Work is especially needed to ensure the necessary conditions for digital transformation are created in rural areas.

5.1 Challenges to connect marginalized and remote communities

A well-developed digital infrastructure, especially in rural areas, is a precondition for digital agriculture and food systems. Although advances in technology and regulatory reform have improved access to ICT for people around the world, there still exists a digital divide. Just as a certain technology (e.g. dial-up Internet) becomes available across income levels, a new technology (e.g. broadband) appears, leaving users in developing countries 'playing catch up'.

Although mobile-cellar subscriptions in the last five years were driven by countries in Africa and Asia and the Pacific, many people still do not own or use a mobile phone and the distribution of ownership is unequal. Access to web-enabled smartphones and fast 3G or 4G internet connections remains particularly limited in rural areas. There will need to be work to address this disparity and to facilitate smartphone ownership and use in areas where it is currently lacking.

Both literacy and education levels also remain particularly low for rural populations in developing countries and LDCs which presents a barrier to the use of digital technologies. Youth unemployment rates are often higher than the country average and this is especially the case in rural areas. Increasingly, employers want employees who are adept at using technology. A lack of e-literacy and digital skills in rural areas means these populations will fall behind in the modern labour market. There is a need for school curricula to incorporate digital subjects, for improved knowledge and skills among teachers and for increased availability of digital technologies in classrooms.

To unlock the full potential of digital agriculture transformation, governments need to create an enabling regulatory environment. Designing and managing digital government programmes requires a high level of administrative capacity which is beyond the capabilities of some countries, particularly LDCs and developing countries. Addressing the digital divide must be made a policy priority and governments should make the socioeconomic case for digitalization of smallholder farming both to the farmers, and to potential private sector investors and start-up businesses. There will need to be significant capacity building among governments in developing countries and LDCs to facilitate this change in policy and regulation.

There is increased interest in data-enabled farming and related services and many new entrants from the technology industry and start-ups. Vast data collection will drive the use of machine learning and AI and new models will need to be developed to make the data useful. So far, the information gathered is often insufficient to inform the comprehensive solutions and partnerships needed to transform smallholder farming into viable, sustainable digital businesses. There also need to be decisions about the ownership and use of data;

manufacturers collect data from their devices and have the opportunity to exploit them, but farmers are often reluctant to share their data without receiving something in return.

Strategies for digital agricultural transformation in developing countries must combine IT infrastructure with social, organisational and policy change.

5.2 Drivers and demands for unlocking digital agriculture transformation

Access to the internet remains the most critical component for unlocking the possibilities of new technologies. Across the globe, smartphones dominate in terms of time spent online and could be a game changer in the agrifood sector in LDCs and developing countries. They create opportunities to access information and services through mobile applications, online videos and social media. Sites like Facebook, Twitter and YouTube present a cost-effective means of communication with, and among, smallholder farmers and other key agricultural stakeholders such as extension officers, agro-dealers, retailers, agricultural researchers and policy makers (Figure 6).

Falling handset prices, increasing internet coverage and the growing youth population create significant opportunities for the use of mobile phones in agricultural areas. However, internet provision and smartphone ownership remain lower in developing countries, and particularly in rural areas, and there needs to be more research into the use of mobile internet and social media in rural communities.

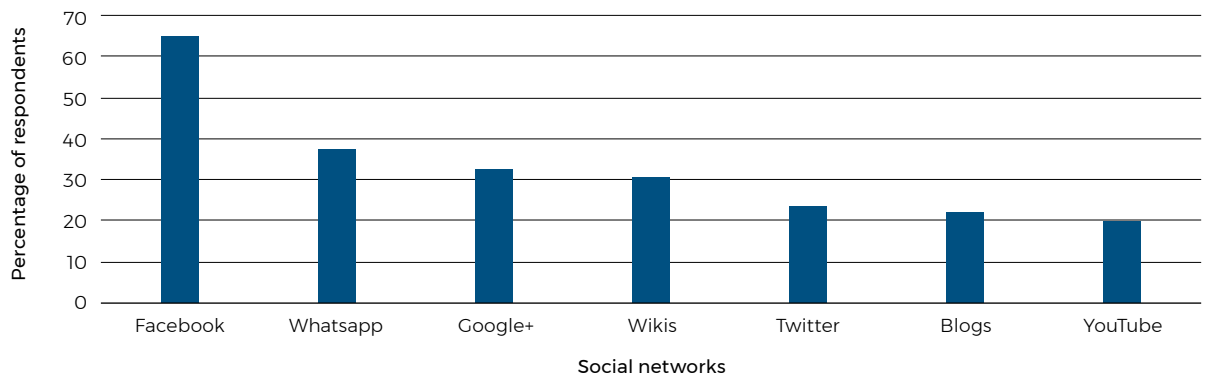
Additionally, not all farmers are quick to adopt ICT. Many lack the necessary knowledge to request or use services, especially as ICT applications in the agrifood sector are relatively new and many e-services are still being developed. It is critical that technologies are properly targeted; if they do not provide the information that farmers need, they will not be adopted.

Digital skills and e-literacy remain a significant constraint to the use of new technologies and are particularly lacking in rural areas, especially in developing countries. The diversity of available digital technologies and a lack of standardisation also present a barrier to adoption. The choice of which technology to use is complex and there is a lack of advisory services to support farmers in these decisions. Education and supporting services must be improved to support the adoption of digital technologies.

Digital technology is already changing the dynamics of the agrifood sector but the process has so far not been systematic. Realising the full potential of digital farming will require collaboration of all players in the agricultural value chain. There is a need for a clear overview on the part of actors working in agrifood and digital products – including private sector, governments and other agencies – on how to exploit the opportunities of digital agriculture.

Farmers have a key role to play and digital technologies provide new opportunities for them to collaborate and innovate. There is also a growing group in the farming sector who have university degrees and specialisations in science and technology subjects. They are often skilled in experimentation and innovative thinking. Youth in the agrifood sector are also often entrepreneurial and willing to take calculated risks to pursue new enterprises.

Figure 5. Social media preferences among agriultural stakeholders (%), 2016.
Source: Bhattacharjee and Saravanan, 2016.



Note: Includes 62 countries.

There is a need for greater support for agripreneurial activities such as: business courses in agriculture, ICT curricula in education, increased capacity and support for innovation hubs and incubators, increased availability of venture capital (especially mid-level financing needed for scaling) and creation of a more favourable business environment. Because the real impact is from the businesses they create, and the amount and kind of employment that their SMEs or digital farms create.

5.3 Future work

Much work is needed in the area of digitalization in agriculture and rural areas. There are some key factors to be considered in this work.

Firstly, a significant challenge in understanding digital agricultural transformation is a lack of systematic, official data on the topic. Much of the data – for example on levels of e-literacy – are only available at the country level with no distinction for urban and rural areas. Meanwhile, data on networks focus only on coverage and do not provide information about the quality or affordability of services. There is also a lack of information about government support and regulatory frameworks for digital transformation; so far, this has been interpreted via proxies including the availability of government e-services and regulations about connectivity and data protection.

A second consideration is that there are significant disparities in the adoption of digital agriculture technologies between developed and developing countries and between global companies and those at a local, community or family scale. Factors including financial resources and education levels influence the adoption of modern agricultural technologies. Small farmers in rural areas are disproportionately disadvantaged as well as facing problems of limited access to infrastructure, networks and technology.

A final factor to consider is that digital agricultural technologies are affected by economies of scale. Adoption is easier for users who can implement them at large scale. Small-scale farmers face a disadvantage compared to large agribusiness actors. This creates disparity between large and small-scale farmers, with a corresponding inequality between developed and developing countries. Transformative digital innovations and technologies are often not designed for the scale at which smallholder farmers operate.

Some specific priorities for future work are:

- Facilitating the collection of better data about digital technologies and digitalisation at the regional and population level, particularly to show differentiated information about urban and rural areas;
- Creation of sustainable business models that provide viable digital solutions for inclusion of small-scale farmers in the digital agriculture transformation process;
- Creation of an index to consider the development of digital agriculture in the context of cultural, educational and institutional dimensions of a given country, both in terms of the availability of basic conditions and enablers for digitalization and the potential economic, social and environmental impacts of the process. This could involve further development of a Digital Agriculture Readiness Index, expanding on previous work by the FAO Regional Office for Europe and Central Asia in 2015. Such an index would help provide context for the development of future digital agriculture strategies for the FAO member countries, which starts with sensitizing countries to the concept of digital agriculture and the importance of digital technologies for the agrifood sector and continues with steps towards the digital agriculture transformation process.

6 REFERENCES

Agfundernews.com. African AgriTech Market Map (available at: https://i0.wp.com/agfundernews.com/wp-content/uploads/2018/02/African-AgriTech-Market-Map-FINAL.jpg)

Baumüller, H. 2015. Assessing the role of mobile phones in offering price information and market linkages: the case of m-farm in Kenya, *EJISDC*. (68) 6:1-16.

Bhattacharjee, S. & Saravanan, R. 2016. *Social Media: Shaping the Future of Agricultural Extension and advisory Services*. GFRAS Interest Group on ICT4RAS discussion paper, GFRAS: Lindau, Switzerland.

Coldiretti, 2018. *Report for the agri-food forum of Cernobbio 2018*. Trieste: Instituto Ixe Srl [In Italian].

Disrupt Africa. 2018. *African tech startups funding report 2018*. Disrupt Africa (available at: http://disrupt-africa.com/funding-report/#)

Downes, L. 2009. *The Laws of Disruption: Harnessing the New Forces that Govern Life and Business in the Digital Age*. Basic Books.

European Commission. 2013. *Strategic Policy Forum on Digital Entrepreneurship. Fuelling Digital Entrepreneurship in Europe: background paper*. 6pp. (also available at: http://ec.europa.eu/DocsRoom/documents/5313/attachments/1/translations)

European Commission. 2019. 2nd Survey of Schools: ICT in Education (available at: https://ec.europa.eu/digital-single-market/en/news/2nd-survey-schools-ict-education)

European Parliament, 2015a. *Industry 4.0: Digitalisaton for productivity and growth*. Brussels: European Parliamentary Research Service.

European Parliament. 2015b. *ICT in the developing world*. Brussels: European Parliamentary Research Service.

European Parliament, 2019. *E-Government Survey 2018*. Brussels: European Parliamentary Research Service.

Fakhoury, R. 2018. *Digital government isn't working in the developing world. Here's why*. The Conversation (available at: https://theconversation.com/digital-government-isnt-working-in-the-developing-world-heres-why-94737)

FAO, 2018. *The State of Food Security and Nutrition in the World: Building Resilience for Peace and Food Security*. Rome: FAO (available at: http://www.fao.org/news/story/en/item/1152031/icode/)

FAO. 2017b. *Information and Communication Technology (ICT) in Agriculture: A Report to the G20 Agricultural Deputies*. Rome: FAO.

GSMA. 2018c. *Enabling Rural Coverage: Regulatory and policy recommendations to foster mobile broadband coverage in developing countries*. London: GSMA Intelligence.

GSMA. 2019a. *The Mobile Economy*. London: GSMA Intelligence.

GSMA, 2019b. Spectrum: What is spectrum? (available at: https://www.gsma.com/spectrum/what-is-spectrum/#)

Hahn, H. P. & Kibora, L. 2008. The domestication of the mobile phone: Oral society and new ICT in Burkina Faso. *The Journal of Modern African Studies*. (46)1: 87–109.

ILOSTAT, 2019. Employment database. Geneva: International Labour Organization. [Data retrieved May 2019]

ITU. 2016. *Measuring Information Society Report*. Geneva: ITU.

ITU, 2017. *Measuring the Information Society Report: Volume 2, ICT country profiles*. Geneva: ITU.

ITU. 2018. *Measuring the Information Society Report: Volume 1*. Geneva: ITU.

Lowder, S.K., Skoet, J. & Raney, T., 2016. The number, size and distribution of farms, smallholder farms, and family farms worldwide. *World Development*. (86): 16–29.

McKinsey & Co. 2014. *Offline and falling behind: Barriers to Internet adoption*. New York: McKinsey and Company.

OECD. nd. *Bridging the Digital Divide* (available at: https://www.oecd.org/site/schoolingfortomorrowknowledgebase/themes/ict/bridgingthedigitaldivide.htm)

UN DESA. 2017 World Population Prospects: Key findings and advance tables. New York: UN DESA.

UN DESA. 2018a. *The 2018 Revision of World Urbanisation Prospects*. New York: UN DESA.

UN DESA, 2018b. United Nation e-government survey 2018. New York: UN DESA.

UN DESA, 2019. *Population, surface area and density*. New York: UN DESA.

UNDP. 2015. *Work for Human Development: Human Development Report 2015*. New York: UNDP.

UNESCO. 2017. *Reading the past, writing the future Fifty years of promoting literacy*. Paris: UNESCO.

UNESCO Institute for Statistics. 2018. *Higher education attendance* (available at: https://www.education-inequalities.org/indicators/higher_1822#?sort=mean&dimension=community&group=all&age_group=attend_higher_1822&countries=all)

USAID, 2018. *Digital farmer profile: Reimagining Smallholder Agriculture*. Washington D.C.: USAID.

World Bank. 2016. World Bank, 2016. *World Development Report 2016: Digital Dividends*. Washington, DC: World Bank.

World Bank. 2017. *Future of Food: Shaping the Food System to Deliver Jobs*. Washington, DC: The World Bank.

http://www.fao.org/e-agriculture/

Contact
Information Technology Division
Food and Agriculture Organization of the United Nations
CIO-Director@fao.org / digital-innovation@fao.org

© FAO, 2019
CA4887EN/1/06.19

Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla 00153 Rome, Italy
www.fao.org