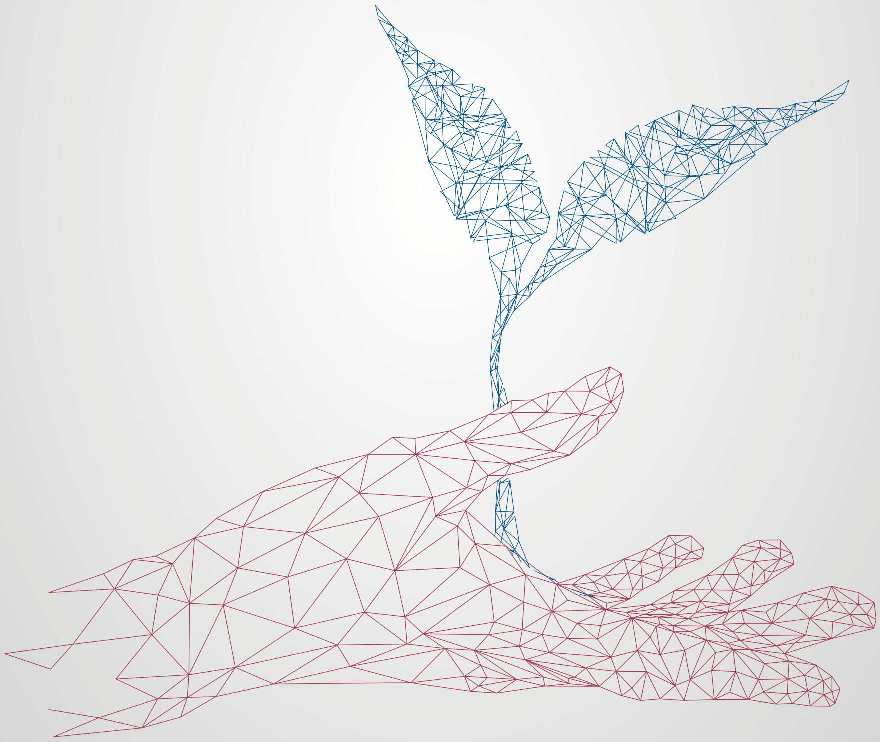
Food and Agriculture
Organization of the
United Nations

DIGITAL TECHNOLOGIES
IN AGRICULTURE AND RURAL AREAS
STATUS REPORT



DIGITAL TECHNOLOGIES
IN AGRICULTURE AND RURAL AREAS
STATUS REPORT

by
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ABBREVIATIONS

AI	Artificial Intelligence
CAGR	Compound Annual Growth Rate
CIS	Commonwealth Independent States
DL	Deep Learning
DLT	Distributed Ledger Technology
ERP	Enterprise Resource Planning
EU-28	European Union 28 countries
FAQs	Frequently Asked Questions
FVC	Food Value Chain
GHG	Green House Gasses
GNI	Gross National Income
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GVC	Global Value Chain
ICT	Information and Communication Technologies
IoT	Internet of Things
IPPC	International Plant Protection Convention
ISPs	Internet Service Providers
ISCED	International Standard Classification of Education
LDCs	Least Developed Countries
LTE	Long Term Evolution
Mbps	Megabits per second
MENA	Middle East and North Africa
ML	Machine Learning
MNOs	Mobile Network Operators
MOOC	Massive Online Open Course
OECD	Organisation for Economic Co-operation and Development
PA	Precision Agriculture
PLF	Precision Livestock Farming
PPP	Purchasing Power Parity
RFID	Radio-frequency Identification
RTK	Real-time kinematic
SEO	Search Engine Optimization
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprise
VC	Venture Capital
VRNA	Variable Rate Nitrogen Application
VoIP	Voice over Internet Protocol
VRPA	Variable Rate Pesticide Application
VRI	Variable Rate Irrigation
VRS	Variable Rate Seeding
VRT	Variable Rate Technologies
WiMAX	Worldwide Interoperability for microwave access

1 INTRODUCTION

Despite the well-known key trends that the future of food and agriculture are facing: such as growing food demand, constraints in natural resources and uncertainties for agricultural productivity (OECD, 2015a), the projected increase in world population from 7.6 billion in 2018 to well over 9.8 billion in 2050 has received a great deal of attention as an influence on world demand for food (UN DESA, 2017). In addition to this, a rapid rate of urbanization is expected in the coming years, with approximately 66 percent of the world's population expected to live in urban areas by 2050, compared with 54 percent in 2014. Therefore, 40 percent of water demand in 2030 is unlikely to be met, and more than 20 percent of arable land is already degraded (Bai *et al*., 2008).

Annual cereal production will need to increase by 3 billion tonnes by 2050 (Alexandratos & Bruinsma, 2012), while meat demand in LDCs will increase by a further 80 percent by 2030 and by over 200 percent by 2050. Although today we have food systems that produce enough food to feed the world, with more than 570 million smallholder farms worldwide (Lowder *et al*., 2016) and agriculture and food production that accounts for 28 percent of the entire global workforce (ILOSTAT, 2019), 821 million people still suffer from hunger.[1] Even though FAO (2017, p. 5) believes that the rising demand for food can be met, it is unclear to what extent this can be achieved in a sustainable and inclusive manner, thus posing the question "How to feed 9 billion people by 2050?". To answer this, we need urgent agrifood system transformation at extraordinary speed and scale-up.

At the same time, the Fourth Industrial Revolution (Industry 4.0),[2] is driving disruptive digital technologies and innovations thus transforming many sectors, and the food and agriculture sector is not exempt from this process. In the recent past, it was difficult to get information to or from smallholder farmers, on their basic needs and problems such as access to inputs, markets, prices, microfinance or learning. The spread of mobile technologies (smartphones), and lately the remote-sensing services and distributed computing, are opening new opportunities to integrate smallholder farmers in new digitally driven agrifood systems (USAID, 2018). The possibility of scaling up these changes exposes potential for the next agricultural revolution, which, without doubt, will be digital.

The majority of the next wave of mobile connections is expected to come from rural communities, of which most are engaged in agriculture activities daily (Palmer and Darabian, 2017). The spread of digital tools has been rapid. Even among the poorest 20 percent in developing countries, 70 percent have access to mobile phones (World Bank, 2016a). More than 40 percent of the global population has Internet access and there are major initiatives under way to connect those left behind, especially in rural areas of developing countries (World Bank, 2016b).

Taking into consideration Industry 4.0, it is expected that over the next 10 years there will be dramatic changes in the agrifood system, driven by advanced digital technologies and innovations (blockchain, Internet of Things (IoT), Artificial Intelligence (AI), Immerse Reality, etc.), changing consumer preferences and demands, the influence of e-commerce on global agrifood trade, climate changes and other factors. To achieve the UN Sustainable Development Goals (SDGs) and going beyond to a "world with zero hunger" by 2030, FAO is calling for more productive, efficient, sustainable, inclusive, transparent and resilient food systems (FAO, 2017 p. 140). The digital agricultural transformation is crucial in providing opportunities for these achievements.

Digital technology is the future and efforts to ignore it to or constitute against such technology will likely fail. Foreseeing several alternative future scenarios, which emphasize the different challenges to unpredictable degrees, can help in working towards implementation of digital agriculture to realize more of its opportunities and avoid possible threats to the global agrifood system such as the "digital divide".[3] This digital divide is no longer associated with poverty and rural areas, of which there are many, but digitization has widened the gap within different sectors and economies, between early adopters and reluctant parties, gender and degree of urbanization. For instance, of all world regions, the strongest growth has been reported in Africa, where the percentage of people using the Internet increased from 2.1 per cent in 2005 to 24.4 per cent in 2018 (ITU, 2018).[4] Weak technological infrastructure, affordability, a low level of e-literacy and digital skills, as well as access to services, and other priorities of emerging economies, are creating a significant digital gap in the possibility of benefitting from the digital agriculture revolution. However, this situation also allows for introduction of different models and leapfrog power in incorporation of digital technologies into the field of agriculture and food. For policy-makers, international organizations, business leaders and individuals, figuring out how to navigate this new scenario may require some radical rethinking, "business as usual" is not the solution.

Living in a world of globalization and dynamic digitalization, led by millennials and the fast pace of technology and innovation, the agrifood sector has been challenged like never before. Shifting the agrifood sector to digitalization is set to be a challenge. Major transformations of agricultural systems, rural economies, communities and natural resource management will be required for digital agriculture as a holistic paradigm to achieve its full potential.

1.1 The digital agriculture

Agriculture has undergone a series of revolutions that have driven efficiency, yield and profitability to levels previously unattainable. The first agricultural revolution (ca. 10,000 BC) enabled humanity to settle, leading to formation of the world's first societies and civilization. Further revolutions introduced mechanization (between 1900 and 1930), the development of new, more resistant crop varieties and the use of agrochemicals ("The Green Revolution" of the 1960s), complemented (from 1990 to 2005) by the rise of genetic modification technologies. The latest, so called "digital agricultural revolution" could help humanity to survive and thrive long into the future. Digital agriculture offers new opportunities through the ubiquitous availability of highly interconnected and data-intensive computational technologies as part of Industry 4.0 (Schwab, 2016).

The rise of digital agriculture could be the most transformative and disruptive of all the industries, because digital agriculture not only will change how farmers farm their farms, but also will transform fundamentally every part of the agrifood value chain. Digital agriculture will affect the behaviour of farmers, and also affect the way that input providers, processing and retail companies market, price and sell their products. It can be applied to all aspects of agrifood systems and reflects a change in generalized management of resources towards highly optimized, individualized, intelligent and anticipatory management, in real time, hyperconnected and driven by data. For example, rather than treating all fields, crops and value chains uniformly, each could receive their own highly optimized management prescriptions and animals could be monitored and managed individually. Value chains could have traceability and coordination at the lowest level of granularity. The desired results of digital agriculture are systems of higher productivity, which are safe, anticipatory and adapted to the consequences of climate change, to offer greater food security, profitability and sustainability.

Market forecasts suggest that digital technologies will transform agriculture and the food sector over the next decade. These technologies will have their own place and impact within the agrifood value chain. Their integration within the agrifood value chain will depend on complexity and stage of maturity of the particular part of the chain. Therefore, in this report we classified digital technologies according to the following structure, based on the complexity and stage of penetration of these technologies in the agrifood sector.

a) mobile devices and social media;

b) precision agriculture and remote sensing technologies (IoT, GNSS, RTK, VRT, PLF, UAV and satellite imagery);

c) Big Data, cloud, analytics and Cybersecurity;

d) integration and coordination (blockchain, ERP, financing and insurance systems);

e) intelligent systems (Deep Learning, Machine Learning and Artificial Intelligence and robotics and autonomous systems).

Research shows that, globally, digitization will lead to higher productivity and wealth. Digitization and smart automation are expected to contribute as much as 14 percent to global GDP gains by 2030, equivalent to about US$15 trillion in today's value. As with all industries, technology plays a key role in the operation of the agrifood sector, a US$7.8 trillion industry, responsible for feeding the planet and employing over 40 percent of the global population (PwC, 2019).

Although the benefits of digital agriculture are convincing, there are a number of challenges that must be addressed in this process of transformational digitalization. For example, there is a lack of standardization in the digital solutions in relation to data, generating problems with data use because of the disparate formats. There is no clarity in relation to the properties of the data, and with that on who will have access to the data and what can be done with it.

It is important to note that this is disparate scenario, in which large international companies predominantly use digital transformation in agriculture in a context of agribusiness. This process also affects other organizations, such as governments, public sector agencies and local agripreneurs, which are involved in tackling societal challenges such as rural livelihood, women and youth unemployment and agripreneurship. In addition, this process generates a challenge in terms of how to take advantage of these emerging disruptive technologies that may affect the economic, social and environmental areas.

The next section presents a framework in which the different elements we have identified in the transformative process of digital agriculture are related, to provide a holistic structure in their analysis. Even when this model is not explanatory, it allows establishment of different levels of analysis and evaluation of the current state of the art of digital technologies in agriculture and food.

1.2 The framework

The structuring of a descriptive model that allows us to identify, as a first measure, those elements that characterize the digital transformation in agriculture and rural areas, to the measure or describe its current state, will permit us to make advances in structuring of a common methodology that serves the identification of the opportunities and risk that the digital transformation brings in this sector. Even when this methodology is descriptive, that is, it does not intend to establish the explanatory mechanisms between the different variables, it is in itself an advance that allows structuring of a number of elements, such as technologies, in a holistic vision where not only is the technology an explanatory variable, but also a series of other elements, such as policies and incentives, business models, and in general the conditions that promote or suppress the adoption of digital transformation. The structure is simplified, and it is based on three main interrelated categories. On the one hand, it establishes the level of maturity of adoption of digital technologies, which can be established at the level of:

a) basic conditions: these are the minimum conditions for use of technology, in which the most traditional correspond to its adaptability, including connectivity (mobile subscription, network coverage, and broadband and Internet access) and affordability; educational systems, literacy and employment (in rural areas and agrifood sector); and policies and programmes (e-strategy) for enabling digital agriculture;

b) enablers for adoption of digital technologies: those capabilities that make possible or drive changes using digital technologies (use of Internet, use of mobile and social media), digital skills, agripreneurial and innovation culture (investment, talent development, sprint programmes).

On the other hand, the areas of impact of applying digital technologies within the agrifood system, include:

c) taking advantage of technology to improve economic (efficiency, productivity, etc.), social and cultural (food security, digital divide, social benefits, women and youth inclusion, fairness, etc.), and environmental impacts (climate change adoption and adaptation, resilience, sustainability, etc.) through the use of different types of resources.

By understanding and measuring the level of digital maturity, it is possible to identify areas of improvement and acceleration that allow the benefits of this transformative process to be achieved. In general, adopting new technology is a starting point, but it is not a guarantee of achieving the expected results, there are many other elements that are necessary, often sufficient, to achieve these results. Too often, success is defined as implementation, not impact. It is for this reason that it is necessary not only to identify it, but to use it as the guiding element of the work that is developed.

1.2.1 FOCUS ON SDGS

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. The Sustainable Development Goals (SDGs) were set to transform the world's economy, society and environment. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, spur economic growth and leave no one behind – all while tackling climate change and working to preserve our oceans and forests.[5]

In this context, the work developed in this report considers the three basic areas as the axes to identify the state of digital technologies in agriculture and rural areas, identifying possible areas for improvement and acceleration. In particular, these axes correspond to:

a) economic: agricultural practices and technologies can contribute to increase productivity, reduce production and logistic costs, reduce food loss and waste, increase market opportunities, bring sustainability at the levels of farmers, value chains and countries, and increase the sector and national GDP;

b) social and cultural: technologies can create an integrating effect at a social and cultural level through the communication mechanisms they provide. However, at the same time, those who do not have the possibility of accessing them (digital divide) are excluded from their benefits. Some factors that influence this exclusion correspond to age, gender, youth, language and rurality;

c) environmental: smart agriculture, or precision and digital agriculture, allows for monitoring and optimizing of agricultural production processes, as well as value chains and delivered products. The use of digital technologies allows prevention and adaptation to climate change, as well as the best use of natural resources.

Even though these areas of work or observation are somewhat generic, they allow us to distinguish how different digital technologies impact on them, some in a specific way, others in a more multifaceted way. A greater analysis is carried out herein, allowing identification of the current state and empty spaces of the application of digital technologies in agriculture and rural areas.

1.2.2 RESOURCES

In this final aspect of the framework, we identify resources that are affected or not considered as an essential element of digital technologies in agriculture and rural areas. The related classification does not intend to be exhaustive but identifies different elements in the digitization process as reported in this document. The resources considered are the following:

a) natural resources: one of the basic elements used in agriculture corresponds to natural resources such as soil, water, forests, etc.;

b) human resources and talent: the need to have, develop and incorporate into digital agriculture is a key element, with this the possibility of considering gender and youth in this process is important for development of local capacities;

c) policy and regulatory framework: the regulatory framework, in conjunction with policies that encourage and regulate the use of digital technologies, provides the necessary incentives for sustainable ecosystem;

d) vision and strategy definition: a clear definition of what we want to achieve (vision) and the mechanisms to achieve it (strategy) show a political will that allows advancement in a guided and sustainable way.

These types of resources allow for measurement of the intensity of their use and how they are impacting the results of the digitalization of agriculture and its adoption in rural areas.

1.2.3 SETTING ALL TOGETHER

Digital transformation is predominantly used in a business context by large international companies, it also impacts other organizations such as governments, public sector agencies and entities involved in tackling societal challenges such as rural livelihood, youth unemployment, gender inequalities and agripreneurship, by leveraging one or more of these existing and emerging digital technologies. In some countries, such as Japan, digital transformation even aims to impact all aspects of life with the country's Society 5.0 initiative,[6] which goes far beyond the limited Industry 4.0 vision in other countries. Society 5.0 aims to tackle several challenges by moving beyond just the digitalization of the economy, towards the digitalization across all levels of the Japanese society and the (digital) transformation of society itself.[7]

This digitalization process brings both risks and benefits. As digital information and tools can be accessed everywhere, the choice of location and partnership for the agrifood industry, agribusinesses and farmers becomes more flexible. However, there are concerns that socio-economic development will concentrate in certain areas, mainly urban, because of better developed digital ecosystems. As well as this, ongoing megatrends such as urbanization and the rise of the middle and rich classes settling in cities (UN DESA, 2018), make it even more likely that only certain areas will gain from such digitalization. In this sense, digitalization could lead to further socio-economic and urbanrural disparities and could possibly deepen the existing digital divide.

For example, the digital divide is a manifestation of exclusion, poverty and inequality and continues to be exacerbated because of the effects of unemployment, poorly functioning digital skilling programmes and sociocultural norms in some economies, depriving women equal access to digital services.[8] FAO and other UN agencies are committed to bridging such digital divides, to ensure that everyone is able to take advantage of the benefits of the emerging information society and that these benefits thereby contribute to sustainable development. The UN General Assembly reaffirmed this commitment in its 10-year review of outcomes of the World Summit on the Information Society (WSIS) in 2015.[9]

The digital divide is centred on two crucial problems. Firstly, poorer communities have limited access to digital technologies because of high costs and a general lack of infrastructure, ranging from intermittent supply of electricity to limited availability of information and communication technology (ICT) facilities. Globally, poorer communities and rural women in the developing world reap the least benefits from the ICT revolution. In South Africa, it was revealed that 35 percent of households saw no relevance in accessing the Internet, primarily because of their socio-economic circumstances (World Bank, 2018). In addition, 16 percent fewer women than men use the Internet in low- and middle-income countries and are also 21 percent less likely to own a mobile phone. On the other side, in India only 25 percent of women in rural areas have access to the Internet compared with their counterparts in urban areas.[10] The second problem is the limited access to training in digital technologies, the poor attainment of digital skilling and the limited access to the opportunities that can be derived from possessing these skills.

1.3 The document

This document is structured into four sections, which advance according to the established methodological structure. The collected background and conclusions are based on existing results, presenting different levels of representation in terms of countries and temporalis, which do not make them completely comparable, but do allow establishment of a “state-of-the-art” of the use of digital technologies in the area of agriculture, and potentially in rural areas. Finally, the impact analysis is approached through identified cases, which are not exhaustive, nor less representative, but show how these digital technologies can generate results in the area of agriculture and food.

Below is the scope of the different sections presented in this report.

- **Section 2.** Basic condition for digital agriculture transformation;
- **Section 3.** Enablers for digital transformation;
- **Section 4.** Impact of digital technologies on agrifood system: case studies evidence;
- **Section 5.** Conclusions and challenges.

2 BASIC CONDITION FOR DIGITAL TRANSFORMATION

Small towns and rural areas have many attractive qualities, such as access to nature, lower cost of living and other lifestyle advantages; however, many of these areas are in decline, as a result of dwindling populations, lower education and lower employment opportunities. Although they have the potential to drive economic growth and innovation, small towns and rural communities often lack the basic IT infrastructure needed to prosper in the digital age. This trend is often amplified in rural communities with large indigenous populations and located in remote areas. Access to digital technology is not only important for smallholder farmers and rural businesses offering digitally enabled products and services, but also essential to support all aspects of businesses: linking with suppliers and information; tapping into workforce talent, building strategic partnerships; accessing intermediary support services such as training, financing and legal services; and, above all, accessing markets and customers. Smallholder farms and local agripreneurs without reliable access to high-quality IT infrastructure are disadvantaged in virtually every aspect of business.

But what if we look at the costs for access to IT infrastructure more broadly and think of this as a foundation for access to the full range of public goods and services, employment and education opportunities? Affordability is highly correlated with the economic status of population. Can rural communities living in poverty in the least developed countries (LDCs) and developing countries afford digital technologies, proper education or gain competitive skills to enter the labour market?

Basic conditions are the foundation in the process of digital transformation of rural areas and the agriculture and food sector. These conditions correspond to those minimum conditions for use of technology, under which the most traditional correspond to its adaptability: connectivity (mobile subscription, network coverage, and broadband and Internet access) and affordability; education attainment (literacy rate, ICT in education and teachers' capabilities); and employment in the rural areas and agriculture and food sector. The potential for rural areas to benefit from IT infrastructure is a persistent question. The previous section of this report presented data on aspects of IT infrastructure, including broadband and Internet access, in rural areas, which suggest that there are major shortcomings in most rural communities. Section 2 now examines data at the global level, concerning the "digital divide" and partly the triple divide for rural communities. In addition, it examines the employment flow in rural areas and particularly in the agrifood sector. Section 3 then goes on to describe policy and regulatory frameworks that provide an enabling environment for liberal and competitive digital markets, level of e-services, both governmental and agricultural and their relevance to the business environment for digital agriculture, as well as the data management, ownership and data policy.

2.1 IT infrastructure and network in rural areas

In the era of digitalization, ICTs[11] became vital for humanity and their daily life activities. ICTs have revolutionized how people access knowledge and information, do business and receive various services. However, access to ICT benefits and opportunities is unequally distributed both across and within countries. Driven by wireless technologies and liberalization of telecommunication markets, the rapid adoption of mobile phones in some of the poorest countries in the world has far exceeded expectations. Recently, the number of people having access to a computer and Internet has been increasing in LDCs and developing economies, but the digital divide when compared with developed economies remains large (European Parliament, 2015).

2.1.1 CONNECTIVITY: MOBILE SUBSCRIPTION AND THE ACCESS TO BROADBAND INFRASTRUCTURE

Several factors influence the digital divide between regions and economies. Countries across the developing world are still struggling to secure critical funding and IT infrastructure deficits in their national plans to address demanding social and economic challenges, particularly in emerging economies, which are characterized by rapid urbanization and growing populations. On the other side, large portions of the world population, mainly those remaining in rural areas remain even more marginalized than before. A large gap in IT infrastructure persists, mainly because of the lack of infrastructure, affordability, lack of skills or lack of relevant local content (UN Broadband Commission, 2017). Millions of people live and work in rural communities, but mobile network operators (MNOs) focus on cities, in which required investment in infrastructure is usually lower and purchasing power of consumers is higher, thus creating a spontaneous gap and leaving a technological vacuum between urban and rural livelihoods. In view of the gap in rural communities' access to knowledge, information and services, many scholars perceive ICTs as an essential tool to fight rural poverty (World Bank, 2011). Indeed, ICTs, in particular the mobile services, have great potential in reaching socio-economic benefits for rural communities in remote areas. The benefits for LDCs and developing economies in adoption of mobiles are mostly in, but not limited to, the agricultural, health and financial sectors (Boekestijn *et al.*, 2017).

2.1.1.1 Mobile-cellular subscription

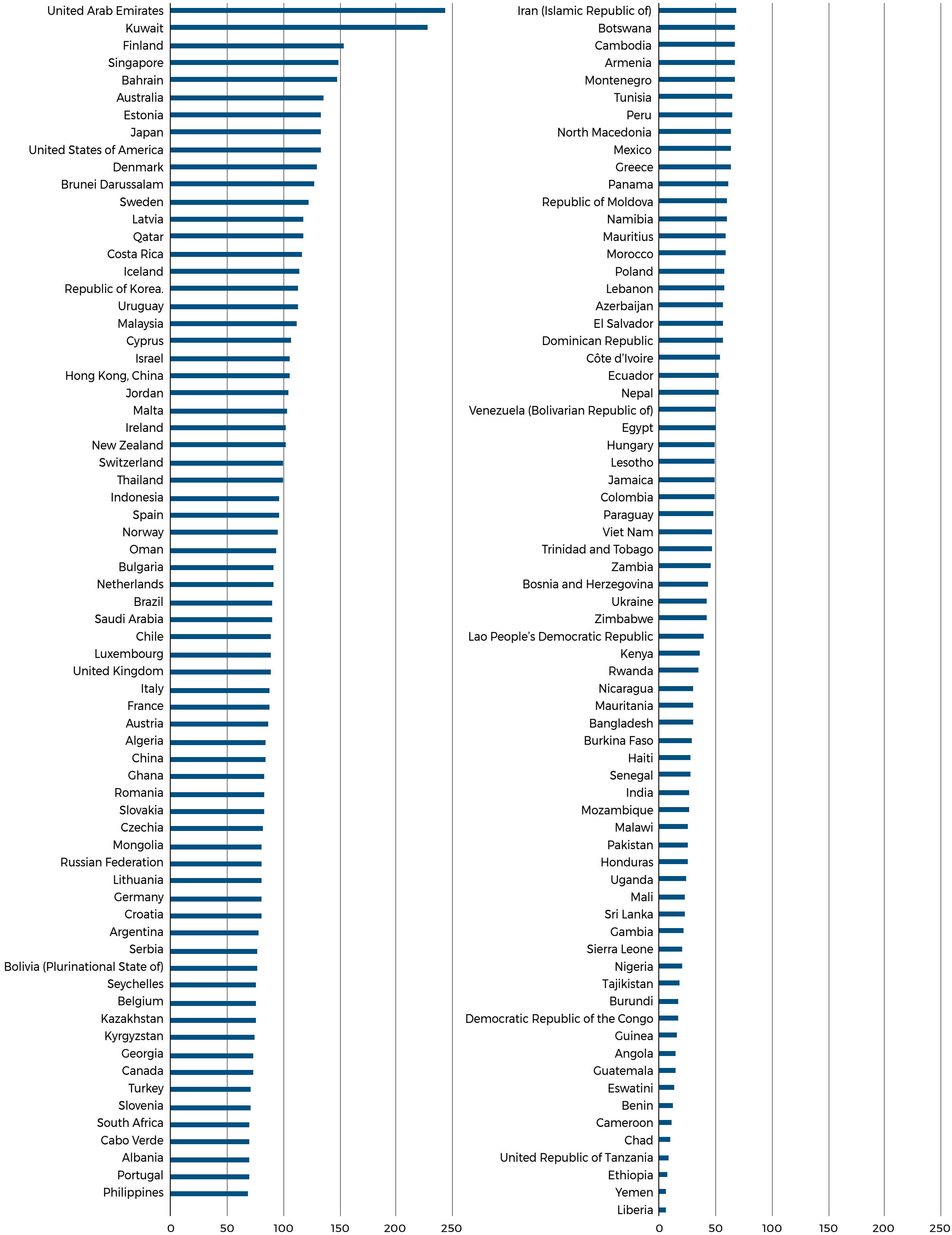
ICT tools are cheaper than ever before, no matter whether rural or urban. Basic ICTs for connectivity are accessible and affordable for many households, especially mobiles both featured and smartphones. There are now more mobile-cellular subscriptions than the number of people on Earth. This is because many people have more than one subscription, to take advantage of network coverage or price on services of more than one mobile service provider, or because they may run businesses and need both private and professional subscriptions. By 2018, 5.1 billion people subscribed to mobile services, which represents 67 percent of the global population. Since 2013, 1 billion new subscribers have been added (representing an average annual growth rate of 5 percent) (GSMA, 2019), yet 3.8 billion people remain offline. Most of those offline live in rural and remote areas and have never had the opportunity to make a phone call, remaining unconnected (GSMA, 2018c). As cities and urban areas across the globe become increasingly connected, often those in rural areas remain isolated. The gap is widening, as are the gender issues. Even when women do own phones, they use them less often than men, and access fewer services beyond voice communication (Isenberg, 2019).

In the coming years, subscriber growth is likely to be driven by a demographic shift, as many young adults become subscribers (GSMA, 2018b). Such an increase in youth demographic groups present MNOs with both opportunities and challenges in terms of connecting rural communities, and future growth opportunities will be concentrated in rural areas and LDCs. Globally, over two-thirds of potential mobile subscriber growth lies in rural and remote regions in LDCs; however, the business case for deploying such networks is expensive and return on investment can be unsatisfactory. Fixed-telephone lines are an expensive investment for many MNOs in attempts to reach rural and remote areas, so for those living there mobile-cellular phones offer an alternative in terms of global connection.

In China, use of mobile phones in the countryside far exceeds that of landline telephones, which was once considered the basic communication tool for rural residents. Only around 29.2 percent of families are still using landline telephones at home, whereas over 92.9 percent own mobile phones.[12] In rural India, the current mobile-cellular market reaches 499 million mobile subscribers, of whom 109 million users own smartphones, and account for 60 percent of the new mobile-cellular subscription growth. Maintaining this pace in terms of share of the market, rural India will reach 1.2 billion mobile-cellular subscribers by 2020 (Kantar-IMRB, 2017). With 444 million mobile subscribers, sub-Saharan Africa is home to 9 percent of all global mobile subscriptions, of which a third (250 million) are for smartphones, and forecasts rise to 690 million by 2025 (GSMA, 2018a).

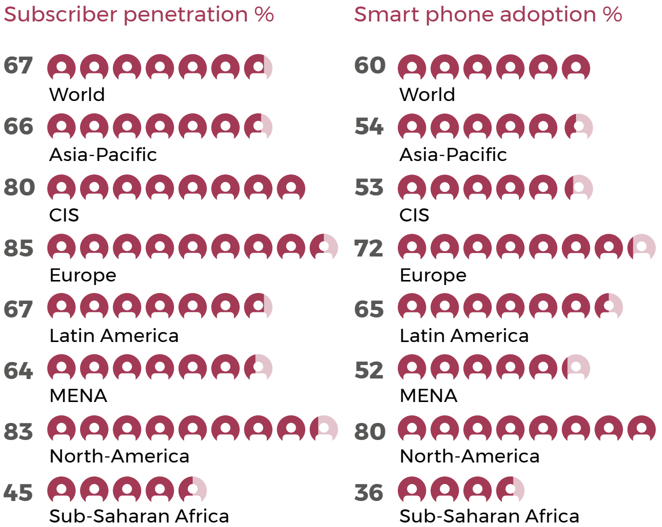
Nevertheless, increased mobile subscription does not mean equal distribution among the population in terms of rural/urban or gender and youth. There are unbalanced wide disparities. In Nepal, urban homes are 100 times more likely to have phones than rural homes (Rischard, 2002). Within India, there are vast differences in mobile-cellular subscription between different states such as Delhi, Karnataka (capital Bangalore considered to be the "Silicon Valley" of India) and Maharashtra (capital Mumbai considered to be the financial capital of India) on the one hand, with 156 and 61 mobile-cellular subscribers per 100 inhabitants, respectively, and, on the other hand, the traditionally agrarian states Bihar and Uttar Pradesh with 30 mobile-cellular subscribers per 100 inhabitants (Pick and Sarkar, 2015). Regional disparities are even higher, with cities such as São Paulo (22 million) and Tokyo (37 million) (UN DESA, 2018) having more fixed-telephone lines than all of sub-Saharan Africa. For the 58 percent of the population of the Democratic Republic of Congo who live in rural areas, such

Figure 2-1 Global mobile-cellular subscription per 100 inhabitants, 2016.
Source: ITU, 2017.



disparities are clearly visible. In contrast, in Cameroon, Ebongue's (2015) research on rural and suburban areas, found that more than 92 percent of the population have a feature or a smartphone and around 8 percent own a tablet, with less than 5 percent not possessing any ICT tool. According to Poushter and Oates (2015), for every 10 people in Ghana, Uganda, Tanzania and Kenya, only one owns a mobile phone. Today, falling handset prices, improved mobile networks and innovations such as pay-as-you-go payment plans, mean that mobile devices are no longer only affordable and available to the urban elite, but are also important assets among the countries' rural communities (Hahn and Kibora, 2008).

Figure 2-2 Subscriber penetration and smartphone adoption (percent) by region, 2018.
Source: GSMA, 2019.



Note: CIS, Commonwealth of Independent States (former Soviet republics); MENA, Middle East and North Africa.

China leads, with the only half the population scoring the most smartphone users at 775 million. The United Arab Emirates has the highest smartphone penetration, with 82.2 percent of its population owning a smartphone, whereas Bangladesh has one of the lowest user-to-population ratios at 5.4 percent.[13] Research by Pew Research Center (2014) shows that mobile-cellular phones are common ICT tools among 90 percent of the adult population in Nigeria and South Africa. In contrast, 17 percent of the population in sub-Saharan Africa do not own a mobile-cellular phone, but more than half of those people sometimes have access to one. However, in LDCs by 2017, the number of mobile-cellular subscriptions reached about 700 million, with a penetration of 70 percent, a positive sign in terms of connection for those 1.2 billion who remain unconnected.

2.1.1.2 Mobile-broadband coverage and regional disparities

More than 87 percent of the world's population are now within range of a mobile signal, of which 55 percent are within range for 3G coverage (GSMA, 2019). Among the world's poorest 20 percent of households, 7 out of 10 have a mobile phone. More households in LDCs and developing countries own a mobile phone, than have access to electricity or clean water (ITU, 2018), but some cannot yet connect to 3G. The regional gap in 3G access is still huge. On the one hand, in Guinea Bissau only 8.2 percent of the population have coverage, whereas on the other hand, developed economies such as those of EU Member States, Barbados, United Arab Emirates and others have 100 percent coverage.

Besides regional and disparities between urban and rural areas, a different proposition is presented by a

Figure 2-3 Global smartphone penetration (percent of population), 2018.
Source: Bank My Cell, 2018.[13]

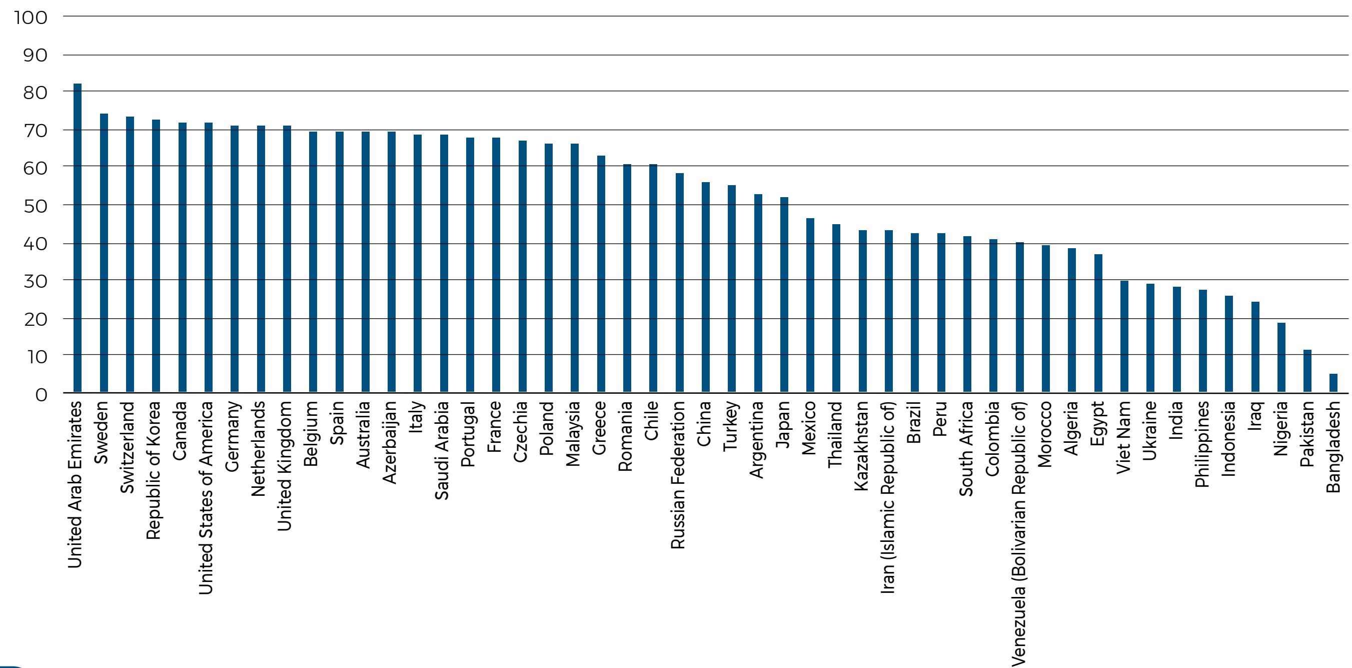
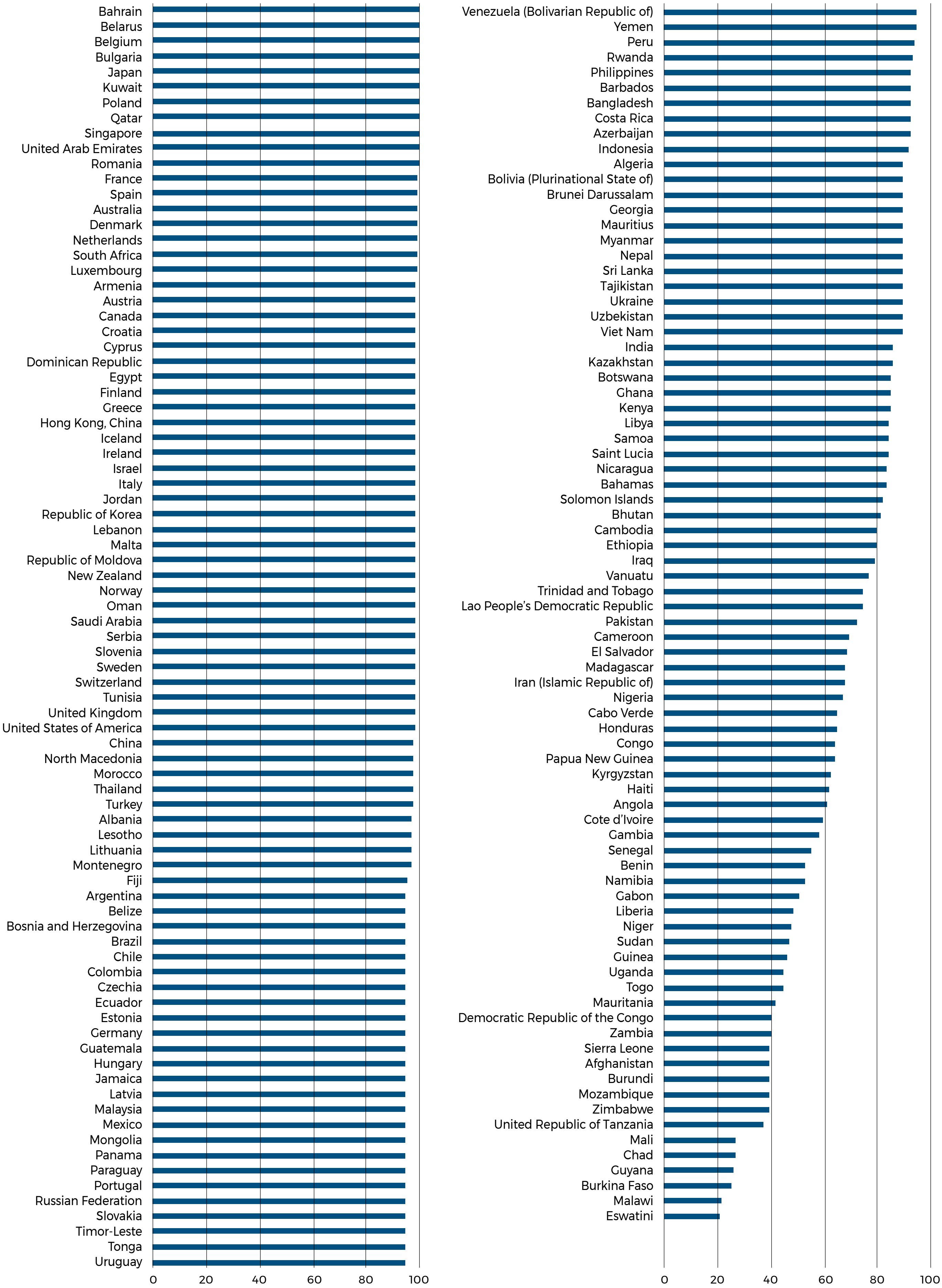


Figure 2-4 Global 3G coverage (percent of population), 2016

Source: ITU, 2017.



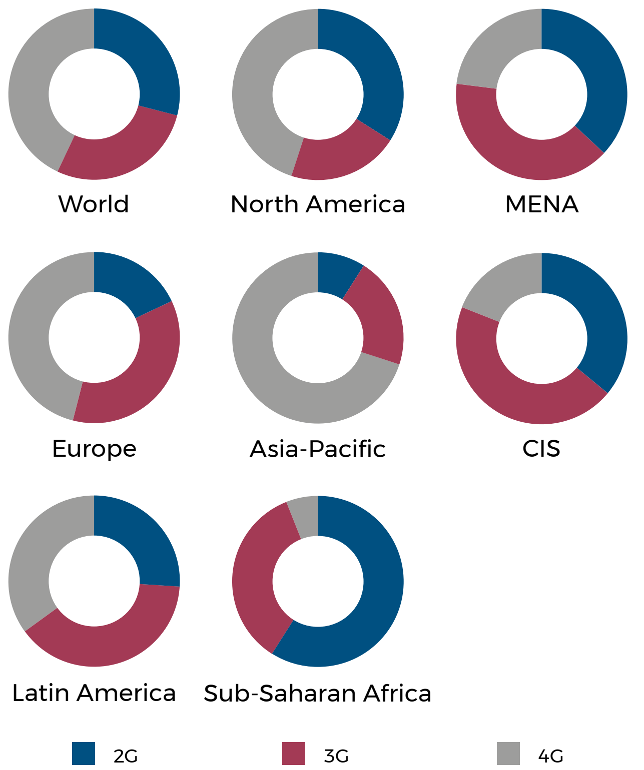
remote village in an emerging economy, tens of miles from the nearest existing infrastructure. In many African countries, 3G deployment beyond the major cities can be as low as 10 percent of the population in rural and remote areas.[14] On a regional level, disparities are even higher, especially those related to the latest long term evolutions (LTE) such as 4G. Only 6 percent of sub-Saharan Africa is covered by 4G, which is seven times lower than Europe with 46 percent and Asia and the Pacific region with 45 percent coverage (GSMA, 2019).

Between 2014 and 2018, 3G coverage reached more than 90 percent of the world's population, adding an additional 1.1 billion people. For the same period, the 4G coverage doubled slightly more than a half, from 36 percent to over 80 percent of the global population, covering an additional 2.8 billion people. However, coverage possibility for those living in rural areas remains limited, especially those in LDCs, in which only around a third of the rural populations are covered by 3G networks (GSMA, 2019).

2.1.1.3 Mobile-broadband subscription

Broadband technology is critical in connecting the 3.8 billion people or the world's "other half" who still do not have access to the Internet.[15] With 45 percent of the world's population living in rural areas and about 20 percent of those in remote areas (UN DESA, 2018),

Figure 2-5 Percentage of 2G, 3G and 4G coverage by region, 2018.
Source: GSMA, 2019.



extending mobile-broadband coverage to connect these 3.4 billion people will be extremely difficult. The rural populations tend to be spread out from village to village across wider areas, making the business model of building an IT infrastructure site in such areas highly unprofitable for MNOs (GSMA, 2017a). Mobile-broadband subscriptions have grown more than 20 percent annually in the last five years. An increasing number of people are moving beyond voice to adopt mobile Internet services, enabling them to participate in the digital economy, reaching 4.3 billion people globally by 2017 (GSMA, 2019).

Despite the high growth rates in developing economies and LDCs, there are twice as many mobile-broadband subscriptions per 100 inhabitants in developed countries as in developing countries, and four times more in developed countries than in LDCs (ITU, 2017). Exceptions are countries such as Malaysia, Oman, Gabon and Thailand, which have more mobile-broadband subscriptions then developed economies such as United Kingdom, Slovakia, China and some others.

More than 219 million EU-28 households (99.9 percent) have access to at least one of the main fixed-broadband or mobile-broadband access technologies (European Commission, 2018); however, the mobile-broadband sector is diverse in disparities: isolated communities in developing countries, holiday homes and single dwellings in the developed world, and each community have their own requirements. In EU-28, rural broadband coverage continued to be lower than the national coverage across all EU Member States. Although 92.4 percent of rural EU-28 homes were covered by at least one fixed-broadband technology in 2017, only 46.9 percent had access to high-speed next generation services such 4G, and the availability of LTE networks reached 89.9 percent of rural EU households by 2017 (European Commission, 2018). In Africa, countries such as Angola, Gabon and Zambia have 5–10 percent availability at the national level; however, there is no likelihood of these networks becoming available in rural areas and remote areas in the near future. This is also seen in Asia and the Pacific region for countries such as Viet Nam, Myanmar, Lao People's Democratic Republic (PDR) and others.

2.1.1.4 Internet access in rural areas

The Internet is the most important enabler of socio-economic development in the twenty-first century, and accessibility in rural areas is a test of the digital divide. Already 3.2 billion people are online, yet 4 billion people remain offline, unable to participate and unaware of the opportunities (GSMA, 2017), especially in LDCs where, in 2015, only 1 in 10 people is online (ITU, 2015). Based on current trends, almost 50 percent of the world's

Figure 2-6 Global active mobile-broadband subscription per 100 inhabitants, 2018.
Source: ITU, 2018.

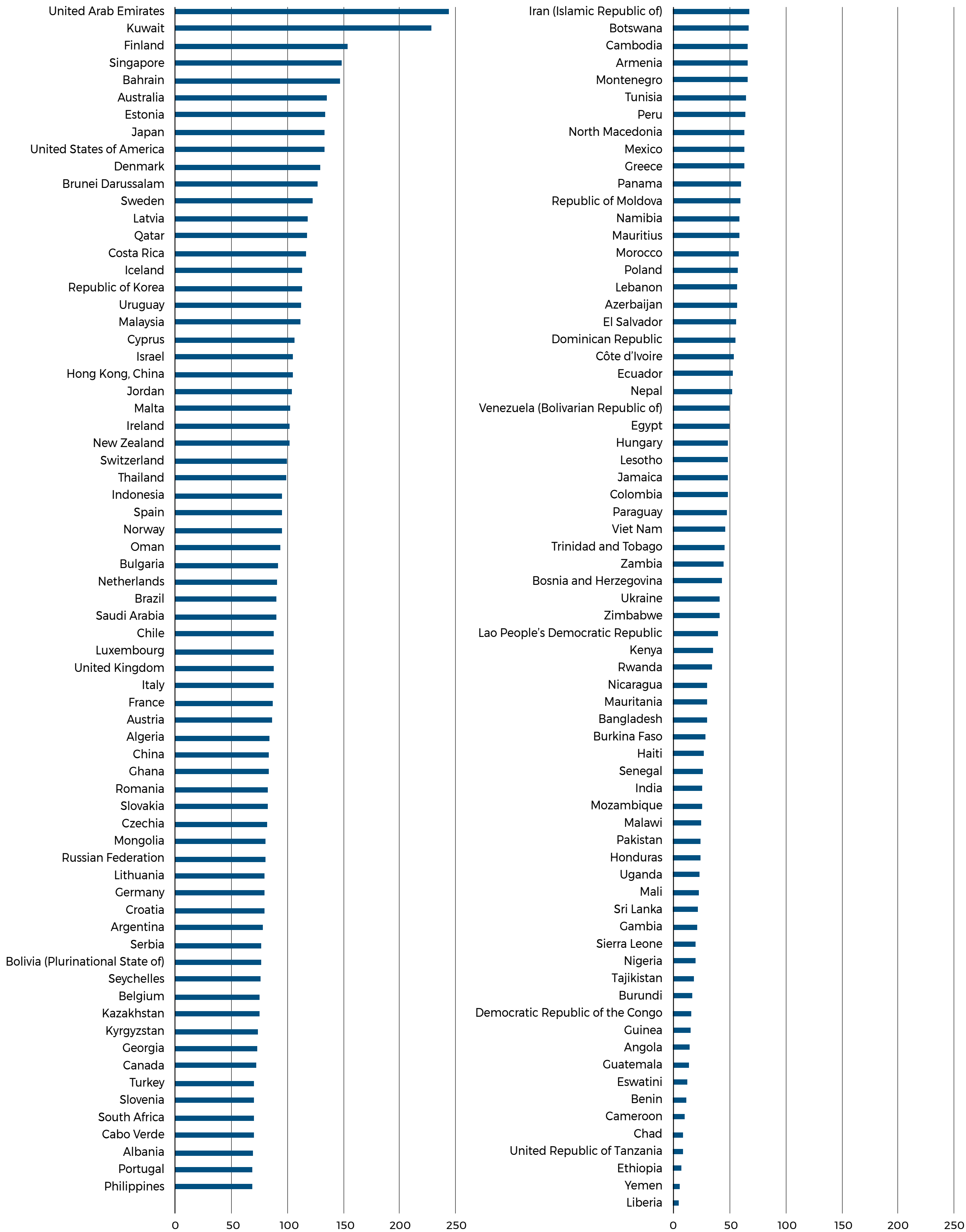


Figure 2-7 Global LTE/WiMAX (worldwide interoperability for microwave access) coverage (percent population), 2016.

Source: ITU, 2017

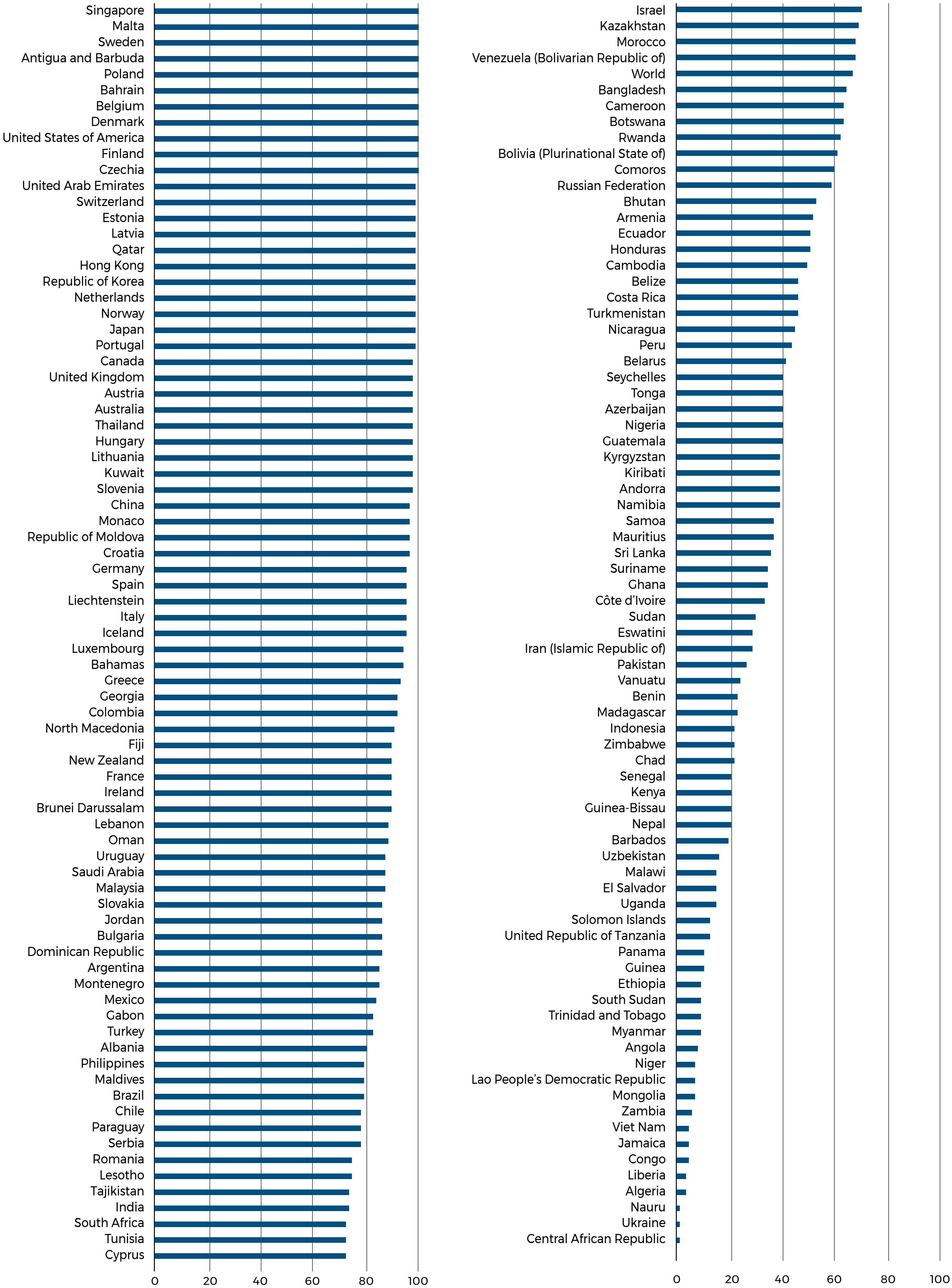
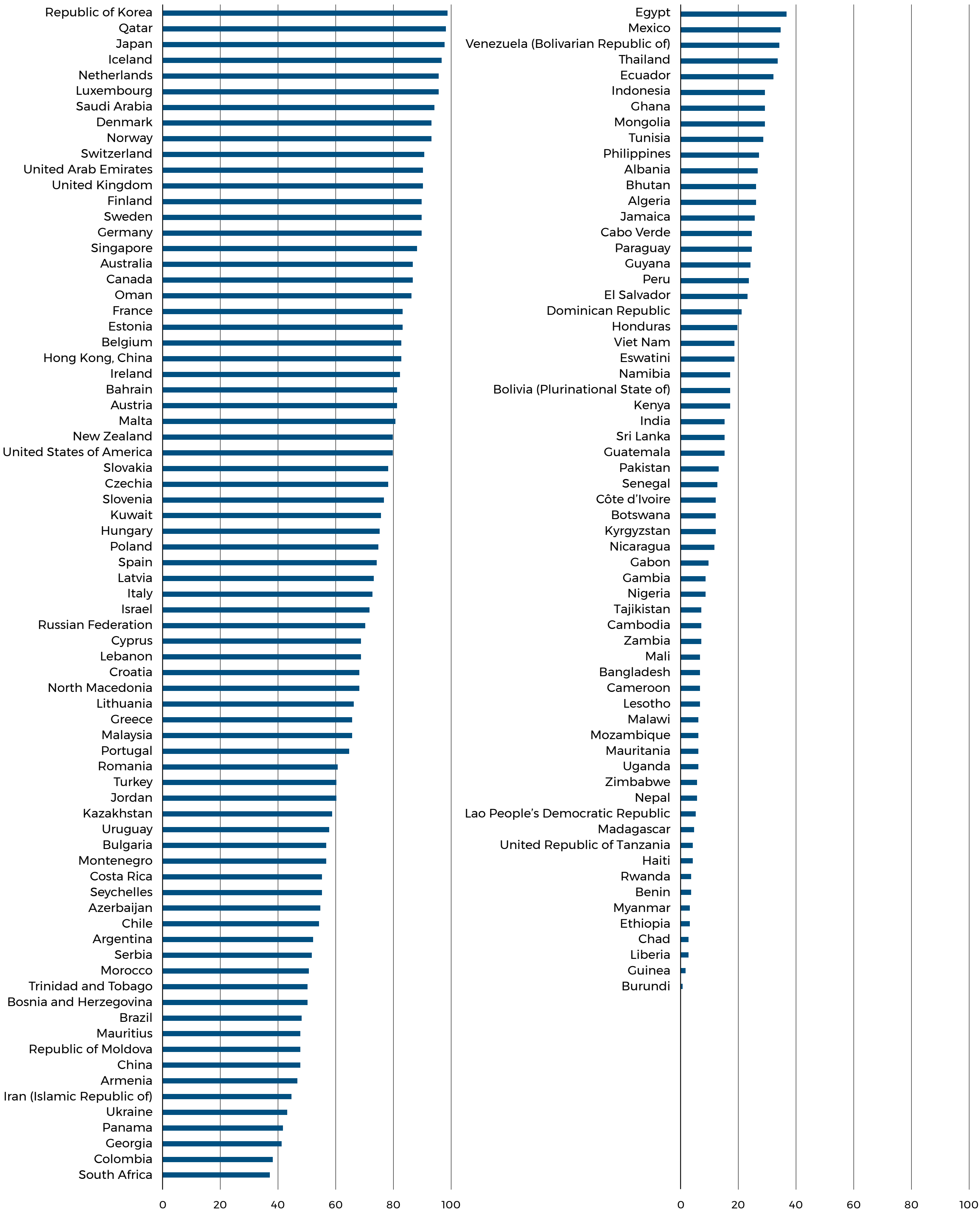


Figure 2-8 Percentage of households with Internet access, 2016.
Source: ITU, 2017.



population will still be offline by 2020 and 40 percent by 2025 (GSMA, 2018d).

Network quality has improved overall, but there is substantial variation across countries. Average download speeds for leading performers are approaching 40 Mbps, but the vast majority (75 percent) of countries has not achieved speeds of even a quarter of this (GSMA, 2019). Europe is at the top of the table for Internet access, with 76 percent of its population able to go online, whereas only 21.8 percent of people in Africa have access to the Internet (UN Broadband Commission, 2017). In some countries, the situation is much poorer than this, for example in Liberia only 3 percent of households have Internet access. Mozambique is performing below average at 16.2 percent, whereas in Tunisia coverage extends to one-third of households (37.5 percent) exceeding the African average. On the other hand, by 2017, the share of EU-28 households with Internet access had risen to 87 percent, a rise of 32 percent from 2007 (Eurostat, 2018a) and four times higher than in Africa.

Although the level of penetration in terms of Internet access is high in both developed and developing economies, the urban/rural digital gap remains strong (La Rose *et al*. 2011; Rivera, Lima and Castillo, 2014). There are no data measuring ICT indicators in rural areas, but rural communities deserve the same access to fast, reliable all-fibre networks as those living in urban areas. The Internet traffic between the United States and Europe is 100 times that with Africa, and 30 times that with Latin America. Rich countries have 95 percent of all Internet hosts and Africa only 0.25 percent. Taking into consideration that Africa has fewer than five fixed-telephones per 100 people, it is very difficult for a country to bind into serious, countrywide Internet connectivity (Rischard, 2002).

Of the 25 least connected countries in the world, 20 are in Africa. Within these 20 countries, only 22 percent of homes have access to the Internet (ITU, 2018). Delivering rural Internet access in LDCs is of particular concern because the marginal benefits of connectivity are generally higher for rural communities in remote areas (e.g. Central African Republic, Mauritania, Bangladesh, Yemen and others) because of their low gross national income (GNI) per capita and socio-economic development level. Similar challenges apply to developing countries.

Figure 2-9 highlights the rural–urban gap in Internet penetration in China (CNNIC, 2017). The figure also shows a slight increase in Internet penetration in rural areas of India, where Internet access rose by 2.5 percent over the last three years. Access to the Internet in LDCs and developing countries remains constrained because of weak and unreliable networks, expensive ICT tools and connectivity (Chair and De Lannoy, 2018).

In Latin America, Internet access seems to be limited in rural households. The access rate is less than 5 percent in most countries, and almost non-existent in Bolivia, Nicaragua, El Salvador, Peru and Colombia. Exceptions are Costa Rica (42.6 percent) and Uruguay (49 percent) (ECLAC, 2019). One of the main reasons is lack of Internet coverage in rural areas, for example 80 percent of Peruvian rural localities lack Internet coverage (FITEL, 2016). With the exception of Uruguay, the rural

Figure 2-9 Internet access in rural/urban areas for some developed and developing economies, 2016–2018.
Source: CNNIC Kantar-IMRB, Pew Research Center and Eurostat, various years.

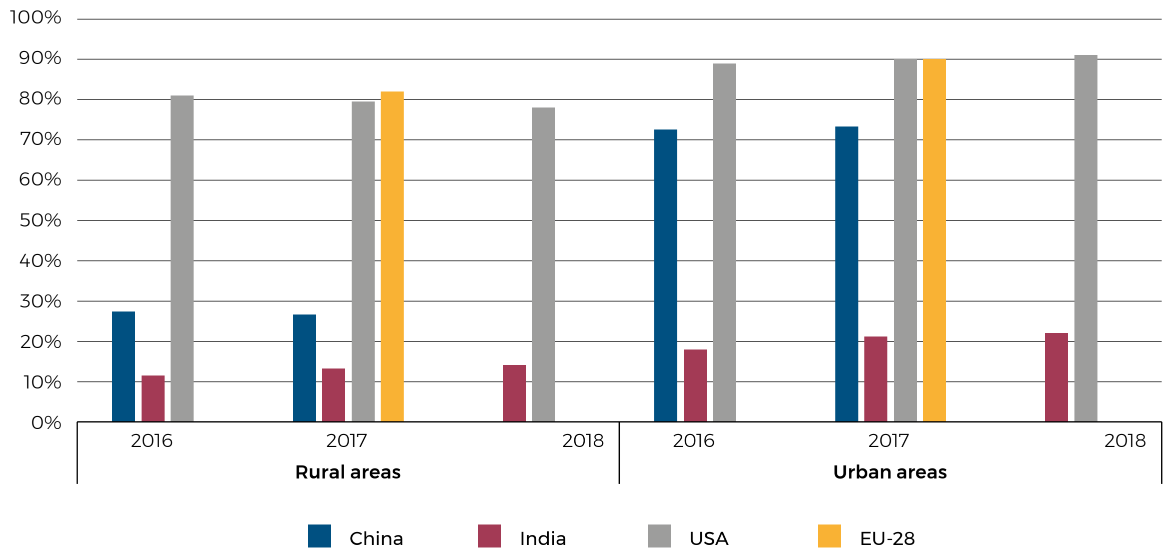
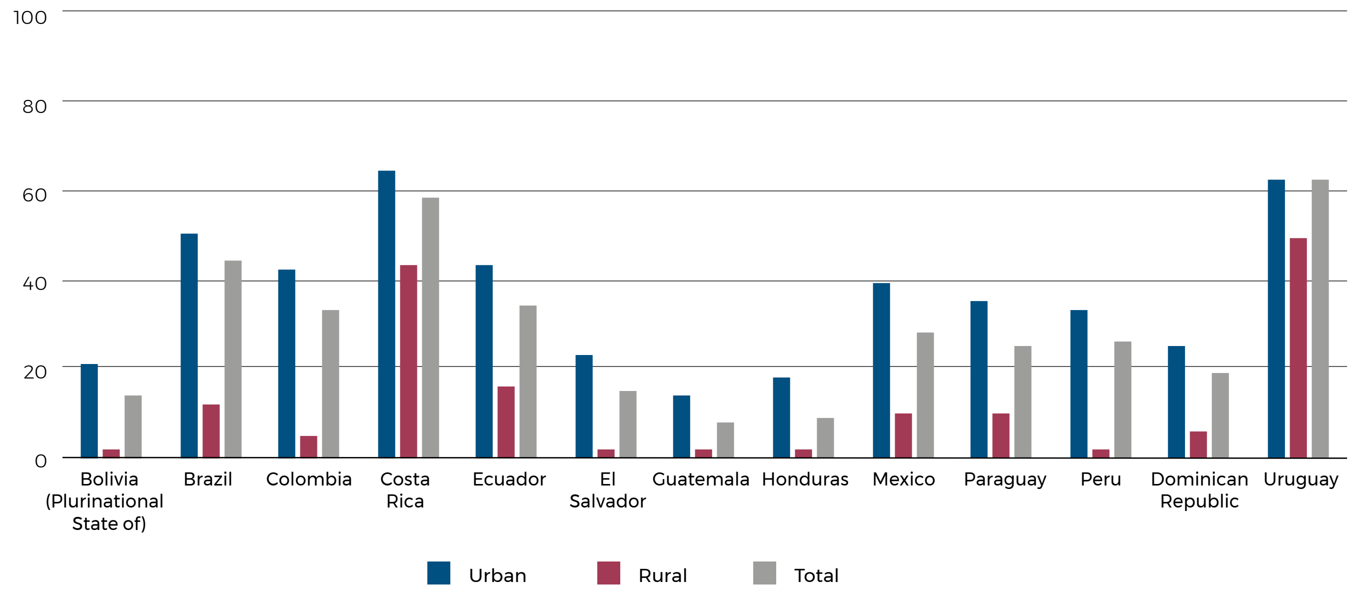


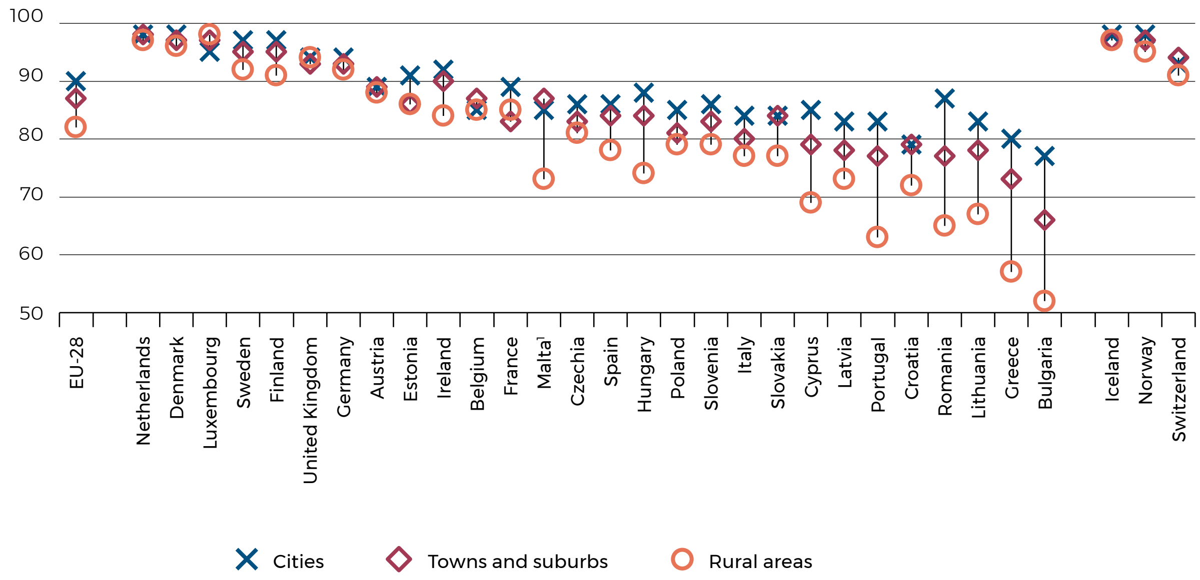
Figure 2-10 Internet access in rural/urban areas in some Latin American countries, 2014.
Source: CEPLSTAT, 2019.



population primarily accesses the Internet outside the home, mostly at work or, in the Central American countries, at public access centres. In general, rural inhabitants in Latin America have fewer opportunities to use the Internet than their urban counterparts, whether at home or in telecentres, Internet cafes, schools or the homes of friends or relatives (ECLAC, 2012).

In developed countries such as the United States and EU-28, the urban/rural gap is smaller than in other economies. The urban/rural gap is only 8 percent in EU-28 (2017) on average, and 13 percent in the United States (2018). Approximately 19 million people in the United States, mostly living in rural areas, lack quality access to the Internet.[16] In EU-28, two-thirds (62 percent) of rural communities accessed the Internet on a daily basis in 2016 (Eurostat, 2018a). However, the situation is not the same in all Member States of EU-28, disparities are visible from country to country. In Bulgaria the gap is 25 percent, whereas in the Netherlands this is only 2 percent, and in Luxembourg it is –2 percent, meaning that rural areas are better connected than the cities.

Figure 2-11 Internet access in households by degree of urbanization in EU-28, 2017
Source: Eurostat, 2018a.



2.1.2 AFFORDABILITY: COSTS OF ICT TOOLS AS A PRECONDITION FOR ADOPTION BY RURAL POPULATION

Availability and affordability of high-speed broadband services in low-income countries remain challenging. A monthly fixed-broadband plan of minimum 1GB data in most low-income countries still corresponds, on average, to more than 60 percent of GNI per capita. In addition, in the LDCs where broadband services are available and offered, the speed and quality are notably lower than in developed countries (ITU, 2017).

Mobile-broadband prices as a percentage of GNI per capita halved between 2013 and 2016 worldwide. The most significant decrease was registered in LDCs, where prices fell from 32.4 percent to 14.1 percent of GNI per capita. In most developing countries, a mobile-broadband service is more affordable than a fixed-broadband service. However, mobile-broadband prices amount for more than 5 percent of GNI per capita in most LDCs and are therefore inaccessible for the majority of the population. In LDCs, on average, an entry-level fixed-broadband subscription is 2.6 times more expensive than an entry-level mobile-broadband subscription (ITU, 2017).

Figure 2-12 Global mobile-broadband prices as percentage of GNI per capita, 2016.
Source: ITU, 2017.

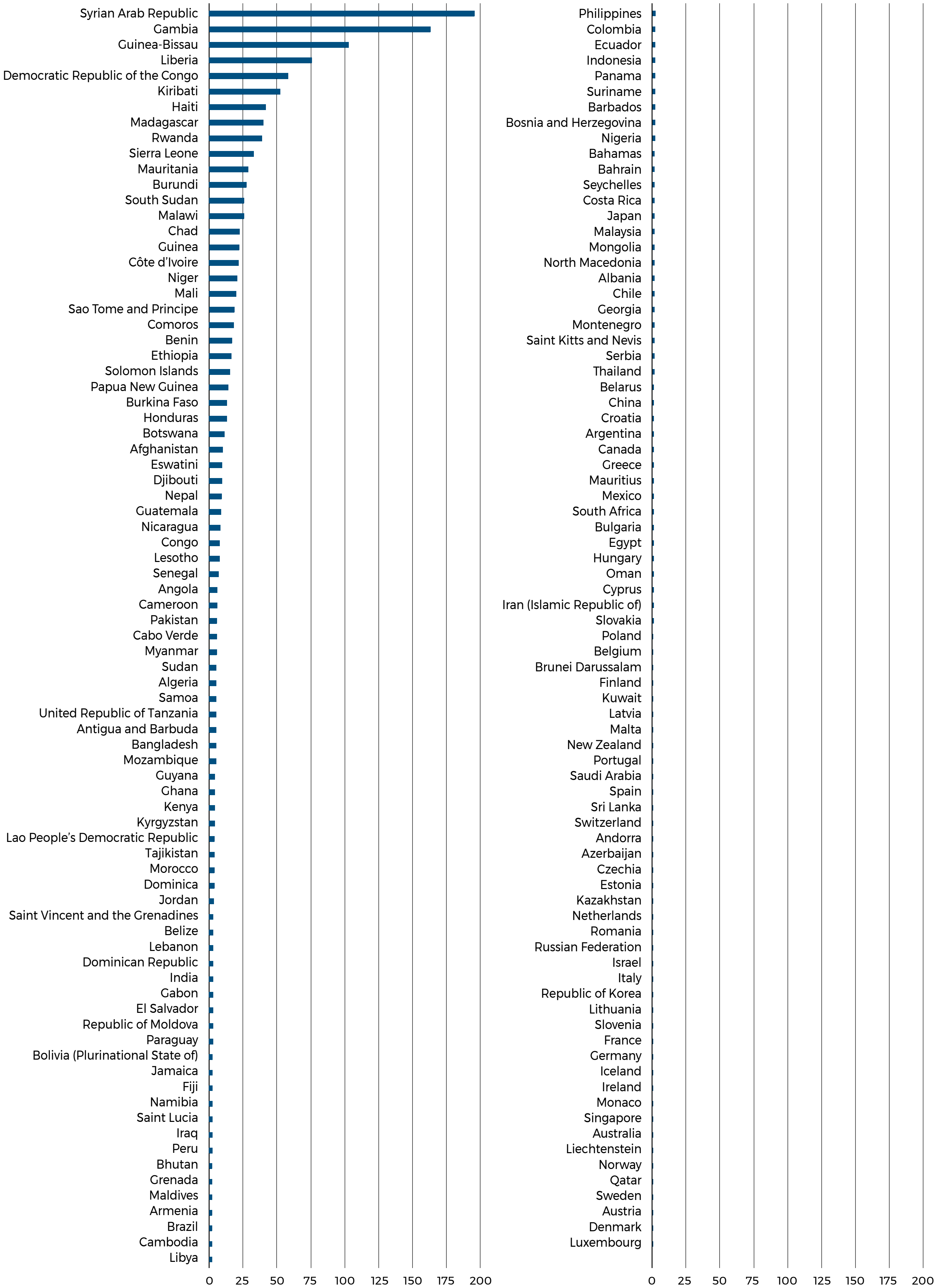
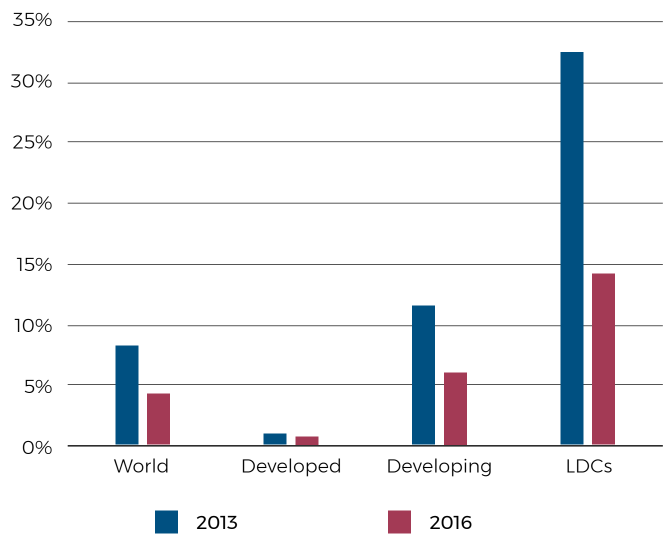


Figure 2-13 Mobile-broadband prices as a percentage of GNI per capita by economic development, 2016.
Source: ITU, 2017



In Mexico in 2018, the average cost of Internet access was US$33 per month. In Canada, the average monthly cost in 2018 was almost US$58, whereas in the United States the price was US$10 higher, i.e. US$68 per month. The United States has the fastest broadband in this region, with an average speed of 25.86 Mbps. Although the Internet speed has improved in the last years, rural areas in the United States still have comparatively poorer service than urban areas, as signals are weaker. In North America, Bermuda is the slowest, with an average speed of 19.48 Mbps.

In South America the average broadband price varies among countries. At the top is Argentina, in which the broadband connection is most affordable and the average monthly price is US$15.51. Argentina is followed by Venezuela and French Guiana, in which the average costs are US$20.03 and US$39.15, respectively. At the bottom of the list is Paraguay, in which the average monthly cost is more than US$210. The islands, however, have remarkably inconsistent prices. In terms of broadband speed, South America is lagging behind compared to other regions. Barbados is South America's fastest country, with an average speed of 17.08 Mbps and Venezuela is at the bottom of the table with average speeds of just 1.24 Mbps.

In Asia, Internet connection generally is affordable. In China the average cost is US$41, whereas in India in 2018 the average broadband cost is US$28.23. However, there are some Asian countries in which Internet prices are notably high, for example in Brunei the average cost of broadband in 2018 was US$123.29, whereas in Laos it was US$239. These two countries are exceptions, rather than the rule. Cheap Internet is provided in Sri Lanka (US$5.65), Russia (US$9.77) and Syria (US$13). Internet speed in this region varies among countries. Both within this region, but also on a worldwide level, Singapore takes the leading position with an average speed of 60.39 Mbps and Japan is in twelfth place globally and the average speed is 28.94 Mbps.

Europe has the world's highest concentration of countries with fast Internet connection and Sweden is Europe's fastest. With an average speed of 46 Mbps. Singapore tops the world table of fastest broadband connection, but Sweden is second, followed by Denmark, Norway, Romania, Belgium, Netherlands, Luxembourg, Hungary. The average monthly broadband cost starts at US$5 in Ukraine, followed by Moldova and Romania, with costs of US$11.28 and US$14.42, respectively. At the bottom of the list are Iceland, Faroe Islands and Switzerland, in which average monthly broadband prices are US$76.66, US$78.58 and US$80, respectively.

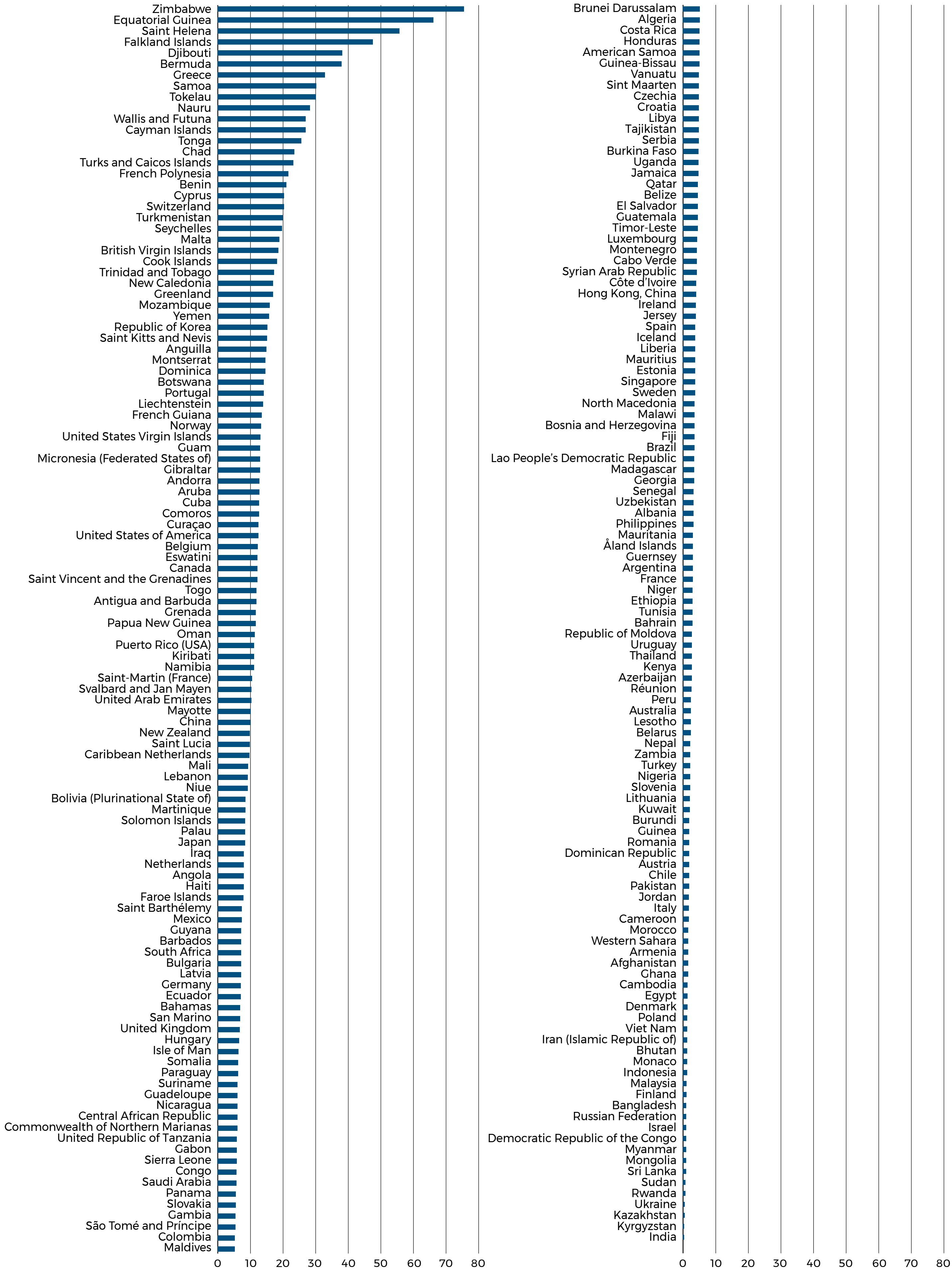
Compared with all other regions, Africa has worst Internet connection, both in terms of price and quality. Even basic smartphones have already fallen below the "tipping point" of US$100 per unit (in Rwanda, Tecno S1 mobile is US$33),[18] so companies are introducing new affordable models specifically geared to the African market (McKinsey & Co., 2013). However, 20 out of the 25 least connected countries are in Africa, and only 22 percent of households in this region have Internet access with only 24 percent of the individuals within these households actually using it (ITU, 2018). Africa is the most difficult place to obtain Internet access and the disparities are huge. In Egypt, the average monthly broadband connection in 2018 cost approximately US$14, but in other African countries such as Burkina Faso, Namibia and Mauritania, monthly average costs are US$202, US$384 and US$768, respectively, confirming that disparities are high in the continent. More than half of urban African consumers already have Internet-capable devices. Africa's smartphone penetration, currently at 25 percent, could reach 50 percent in leading countries and 30 percent overall. This translates into 300 million new smartphones being sold in Africa in the decade ahead. PC, laptop and tablet penetration could double, to 40 percent (McKinsey & Co., 2013).

2.1.3 CONCLUSION

Mobile-cellar subscriptions in the last five years have been driven by countries in Asia and the Pacific region, and Africa. Growth was minor in the Americas and the former Soviet republics, while there was a decline observed in Europe and the Arab States. However, many people still do not own or use a mobile phone. Increased mobile subscription does not mean equal distribution among a population based on rural/urban or gender and youth; there are unbalanced wide disparities. Currently,

Figure 2-14 Average cost of 1 GB mobile data (per month in US$), 2019.

Source: Cable, 2019.[17]



4G is becoming the leading mobile technology across the world, with 3.4 billion connections accounting for 43 percent of the total. However, coverage possibility for those living in rural areas remains limited, especially those in LDCs, where only around a third of the rural populations are covered by 3G networks.

Smartphones are slowly overtaking the feature phones and remain the focal point of the consumer Internet economy, with the range of connected devices (and therefore Internet access channels) being greater than ever. Enabling an environment for smartphone penetration is a possibility for improving Internet connection. Both trends, in terms of smartphones and mobile broadband have seen faster growth in developing countries than in developed countries. However, despite such high growth rates, there remain twice as many mobile-broadband subscriptions per 100 inhabitants in developed countries as in developing countries, and four times as many in developed countries as in LDCs.

To summarize, almost the entire population of the world (96 percent), now lives within reach of a mobile phone network. Furthermore, 90 percent of people can access the Internet through a 3G or higher-quality network. Altogether, this means we are not far from the Connect 2030 Agenda Target of 96 percent of the world population being covered by Internet services by 2023.

Today, many people have access to Internet, but many do not actually use it and the full potential of the Internet remains untapped. Indeed, Internet access is even more unevenly distributed, as the level of penetration is high in both developed and developing economies, but the urban/rural gap remains wide. Despite overall mobile-cellular prices and mobile-broadband prices decreasing in recent years, affordability of ICT services is still one of the key barriers to ICT uptake and remains a challenge in the majority of LDCs. Affordability is the main barrier to mobile-phone ownership. In the world's LDCs, a fixed-broadband plan with a minimum of 1GB of data per month still corresponds, on average, to over 60 percent of GNI per capita. In addition, in those LDCs in which the service is offered, speed and quality are usually lower than in developed countries.

2.2 Educational attainment, digital literacy and employment among rural communities

At record speed, digital technologies are fundamentally changing the way people live, work, learn and socialize everywhere. They are giving new possibilities to people to improve all areas of their lives, including access to information, knowledge management, networking, social services, industrial production and mode of work. However, those who lack access to digital technologies and the knowledge, skills and competencies required to navigate them, can end up marginalized in increasingly digitally driven societies. Literacy, introduction of digital tools in the educational systems and rural employment are causes that can navigate rural communities, especially youth and women being digitally native in the digitally driven society and drive the closure of the digital divide.

2.2.1 LITERACY RATE AND THE GAP BETWEEN URBAN AND RURAL AREAS

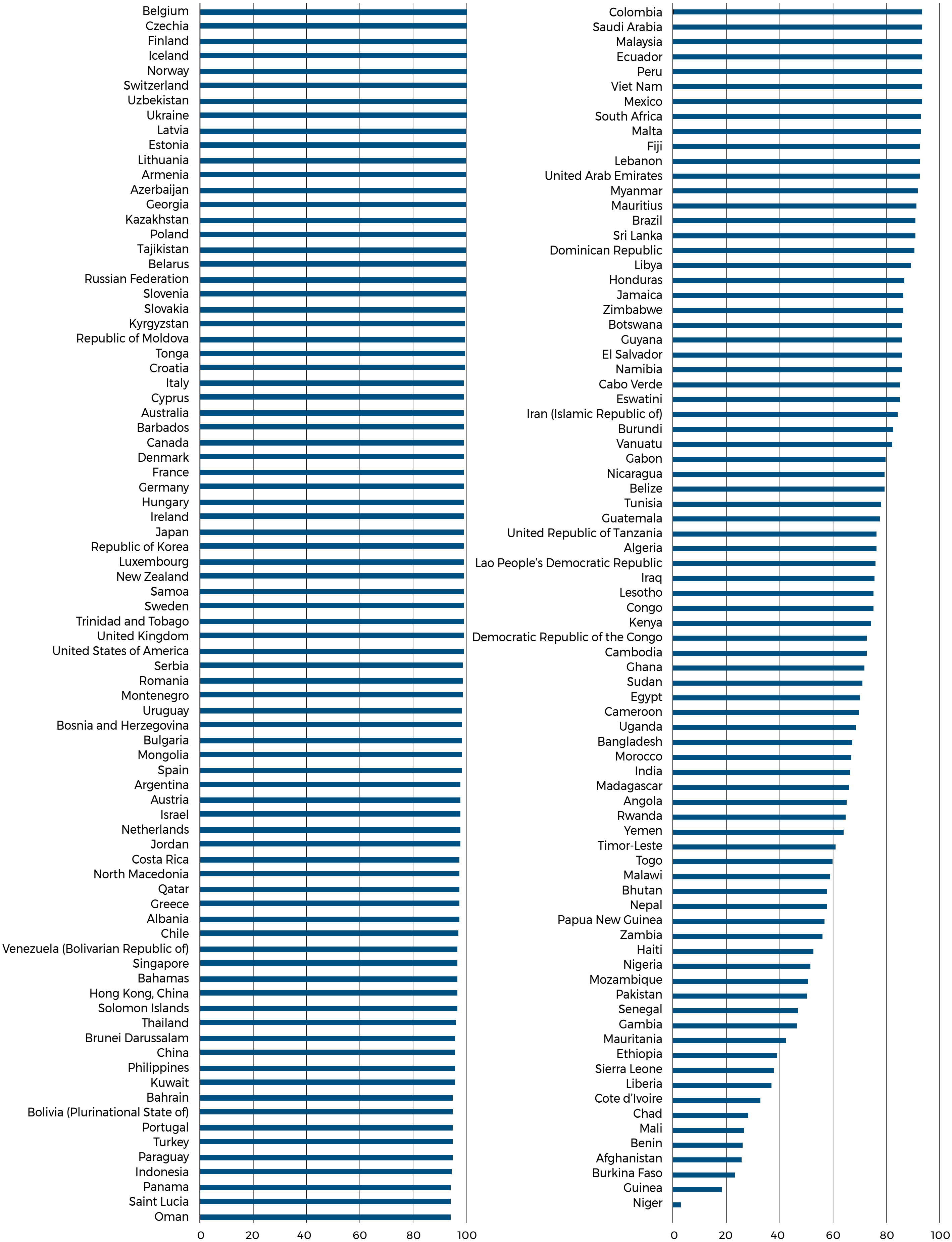
Although literacy is one of the high priorities of the SDGs, the United Nations Educational, Scientific and Cultural Organization Institute for Statistics (UIS) (2017) data show that 750 million adults (two-thirds of whom are women) still lack basic reading and writing skills. Of the illiterate population, 13.6 percent were between the ages of 15 and 24 years (UIS, 2017).

Southern Asia is home to almost one-half of the global illiterate population (49 percent). In addition, 27 percent of all illiterate adults live in sub-Saharan Africa, 10 percent in East and Southeast Asia, 9 percent in North Africa and West Asia, and about 4 percent in Latin America and the Caribbean. Many Latin American countries made 40–50 percent gains in literacy during the twentieth century; however, despite such improvements, there remains a wide disparity between nations in this region. At the turn of the twenty-first century, half of the population in poor countries such as Haiti remained illiterate. Less than 2 percent of the global illiterate population live in the remaining regions combined (Central Asia, Europe, North America and Oceania), in which rates are at or near 100 percent in most countries.

The lowest literacy rates are observed in sub-Saharan Africa and in Southern Asia. Adult literacy rates are below 50 percent in the following 20 countries: Afghanistan, Benin, Burkina Faso, Central African Republic, Chad, Comoros, Côte d'Ivoire, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Iraq, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone and South Sudan (UIS, 2017). In Burkina Faso, Niger and South Sudan, literacy rates are still below 30 percent. On the other hand, as a result of 12 percent of GDP spending on education, Lesotho has one of the highest literacy rates in Africa with about 85 percent of the adult population being literate. Unlike most countries, Lesotho has a higher female than male literacy rate.[19]

Younger generations (aged 15–24 years) are progressively better educated than older generations, reflecting

Figure 2-15 Global literacy rate (percent of population), 2017.
Source: UIS, 2017.



increased access to schooling. Globally, the youth literacy rate increased from 83 percent to 91.4 percent over two decades, while the number of illiterate youth declined from 170 million to 115 million. In 2015, the youth literacy rate stood above 95 percent in 101 out of 159 countries where data are available (UNESCO, 2017). And it is particularly promising that this intergenerational change is happening especially quickly in the least educated regions of the world. Youth literacy rates remain low in several countries, most in sub-Saharan Africa, at less than 50 percent because of low access to schooling, early school leaving or a poor quality of education. However, even when universal primary education is within reach, some countries, such as Malawi and Zambia, show low youth literacy rates (UNESCO, 2017). Bhutan and Nepal in southern Asia, and Algeria, Eritrea and Togo in sub-Saharan Africa, had the biggest increases in youth literacy over the past 50 years. The biggest improvements in youth literacy are observed in Algeria and Bhutan. They went from very low youth literacy 50 years ago to a significantly higher share of youth with basic literacy skills (94 percent and 87 percent, respectively) in 2016, mainly because of increased access to primary schooling (UIS, 2017).

The youth literacy rate increased the most in South and West Asia (from 85.6 percent in 2012 to 88.6 percent in 2016) and sub-Saharan Africa (from 73 percent to 75.5 percent). To a lesser extent, progress was also observed in all other regions (UIS, 2017).

Despite 60 percent of the countries and areas for which data are available having eradicated or almost eradicated illiteracy among youth, regional and gender disparities persist. Literacy is lowest in the rural areas of LDCs and higher among males than females. In sub-Saharan Africa the gap is largest, only 54 percent of youth in rural areas are literate, whereas in urban areas this number is 87 percent. For example, in Niger, only 15 percent of youth in rural areas can read a simple sentence. In Burkina Faso and Chad this number is 19 percent, and somewhat better in Guinea and Cote d'Ivoire at 35 percent. In recent decades in Latin America and the Caribbean, the gap has been rapidly decreasing. In Bolivia it is only 2 percent, while in countries such Barbados, Columbia, Uruguay and St. Lucia literacy between urban and rural youth is equal. In this region Haiti has the highest illiteracy among the rural youth population at 74 percent (UNESCO, 2017).

Indeed, the gender gap is correlated with the regional disparity. Figures 2-18 and 2-19 clearly show that those regions and LDCs with higher gaps in youth literacy between urban and rural areas also show higher gender gaps between youth populations. In sub-Saharan Africa the gap is 18 percentage points, whereas in LDCs in general it is 23 percentage points. In East and Southeast Asia, male youth are 14 percent less literate than the females. In Latin America and Caribbean this gap is just 2 percent, while in Europe and North America the gap is already closed and gender literacy equality is achieved among the youth population. The largest inequality gap is seen in Afghanistan at 50 percentage points, followed by Guinea 45 percentage points, based on latest available data from UNESCO (2019).

Globally, in 2016, almost 90 percent of women aged 15–24 years had basic literacy skills. Women thus have made more progress than men since the 1960s. Improvements

Figure 2-16 Youth literacy rate 15–24 years by regions (percent of total youth population), 2012–2016.
Source: UNESCO, 2019.

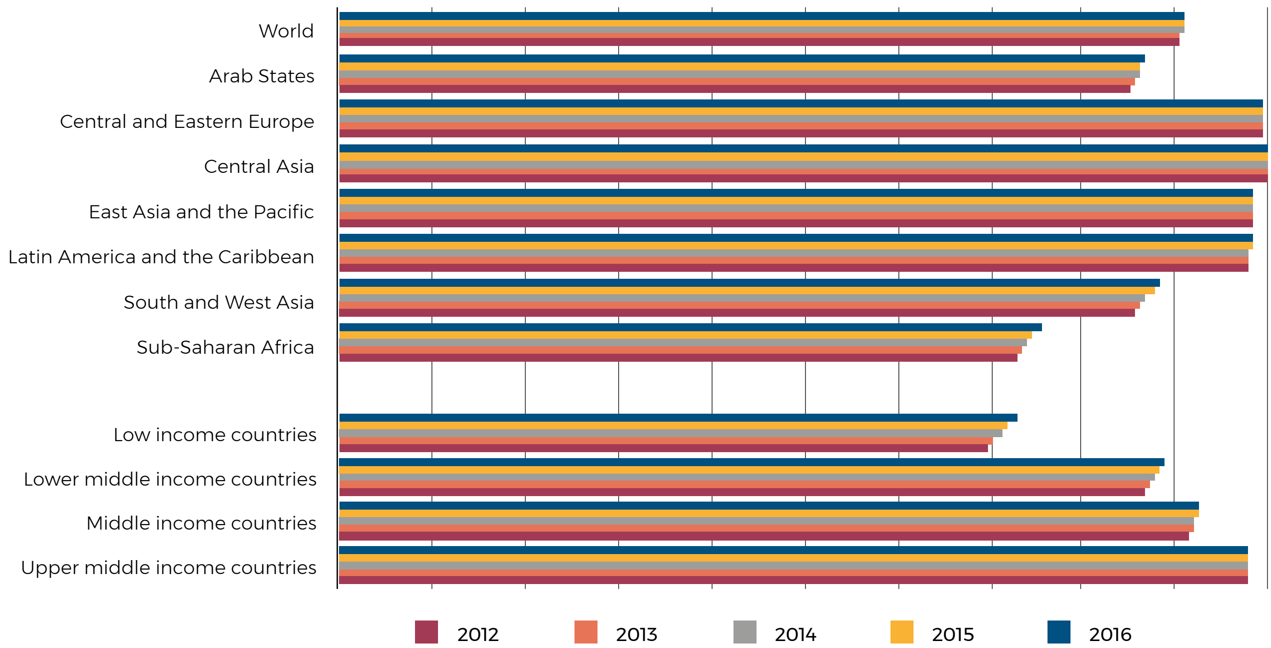


Figure 2-17 Youth literacy rate by degree of urbanization, various years.
Source: UIS Database, 2019.

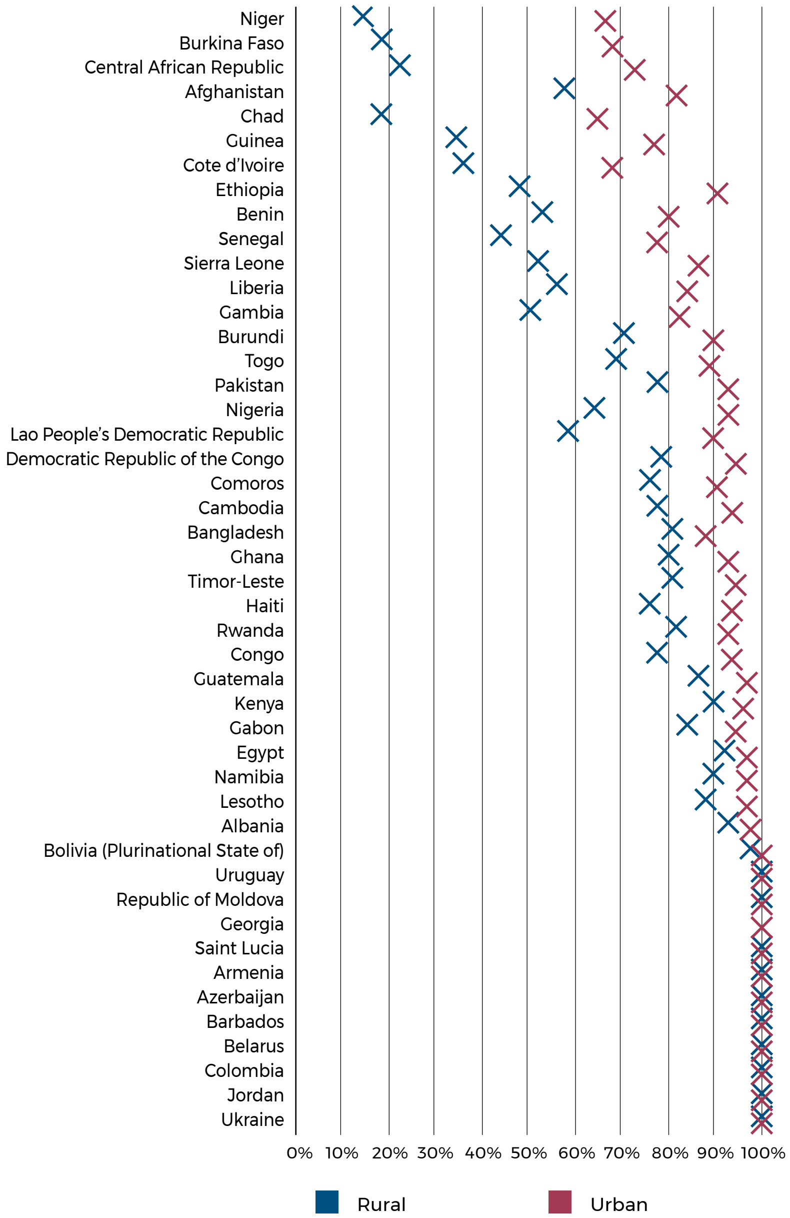


Figure 2-18 Youth literacy rate by gender, various years.
Source: UIS Database, 2019.

in female youth literacy are significantly greater than for males in all regions of the world, except in Central Asia and Europe and North America, where there was hardly any gender gap in youth literacy 50 years ago. Southern Asia and sub-Saharan Africa are the regions in which women progressed the most. Five decades ago, in Central Asia and Europe and North America, only one-quarter of young women were able to read, but nowadays young women fare significantly better with 86 percent and 72 percent being literate, respectively. In northern Africa and western Asia, a substantially larger share of young women (88 percent) is also literate compared to 50 years ago (43 percent). Countries that have made the greatest progress include Algeria, Cabo Verde, Cambodia, Malawi, Oman, Rwanda and Uganda. In these countries, the gender gap in youth aged 15–24 years has been, or is almost, closed (UIS, 2017).

2.2.2 INTRODUCTION OF ICTS TO THE EDUCATIONAL PROCESS

Educational systems and attainment must keep pace with the process of digital transformation. The nature of the target audience of the modern educational system, mostly youth who are digitally connected, means that teachers must possess appropriate digital skills and education must adapt to accommodate expectations of future generations. Most students in developed countries have grown-up online, using advanced technologies that require advanced digital skills and will expect their learning and education environments to be at the same levels as their day-to-day lives.

Introduction and adoption of digital technologies has made education more accessible than ever before. Introduction of digital tools such as online videos, Massive Open Online Courses (MOOCs), mobile apps and challenge-based games in the process of formal and non-formal education have boosted the process of achieving e-literacy among the youth population, especially those in rural areas. Within schools, introduction of computer and IT courses and teachers teaching through creative methods using digital tools is becoming reality, not only in developed but also developing countries.

But, not all youth have the opportunity to access computers or Internet at schools or home. Access to ICTs in LDCs is lagging behind that of developed countries, leading to the possibility of a widening digital divide and disparities between regions. An OECD report (2015a) highlights the importance of bolstering students' ability to navigate through digital texts and makes clear that all students first must be equipped with basic literacy and numeracy skills so that they can participate fully in the hyperconnected, digitized societies of the twenty-first century.

Therefore, the report suggests that the connections among students, computers and learning are neither simple nor hard-wired and the real contributions ICT can make to teaching and learning have yet to be fully realized and exploited. In 2012, 96 percent of 15-year-old students in OECD countries reported that they had a computer at home, but only 72 percent reported that they used a desktop, laptop or tablet computer at school, and in some countries fewer than one in two students reported doing so (OECD, 2015a). In EU-28, 50 percent of 15-year-old students were in highly equipped schools, but another 20 percent almost never used a computer during lessons. The shares of students attending highly digitally equipped and connected schools differ widely across EU-28, ranging from 35 percent (ISCED 1) to 52 percent (ISCED 2) to 72 percent (ISCED 3)[20] (European Commission, 2019). In contrast, schools in South Africa are relatively well equipped with ICTs. More than 60 percent of primary schools in South Africa, Botswana and Namibia have radio, television or computers. For schools in Mauritius and Seychelles this figure increased to more than 90 percent. Although the impact of computers has not been directly assessed, it has been reported that students in these countries attained higher achievements and better grades (Hungi, 2011).

Figure 2-19 Access to computers and Internet at school and at home for OECD and some partner countries, 2012.
Source: OECD, 2015a.

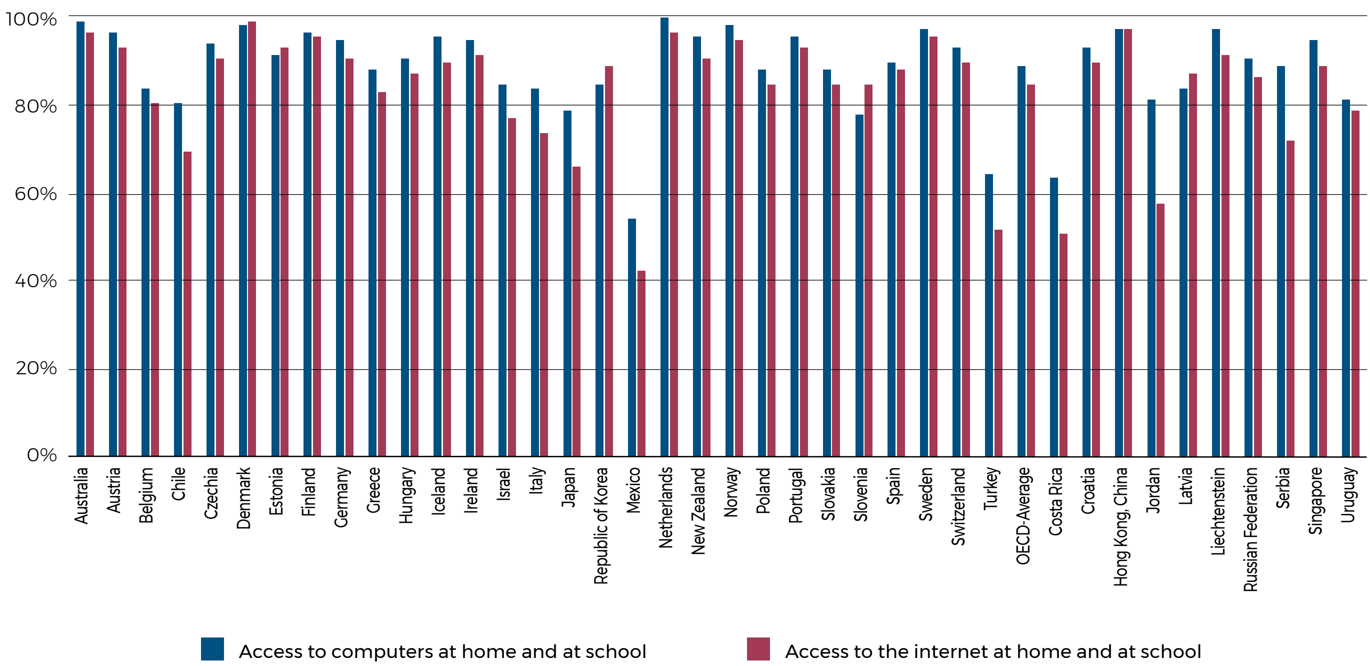
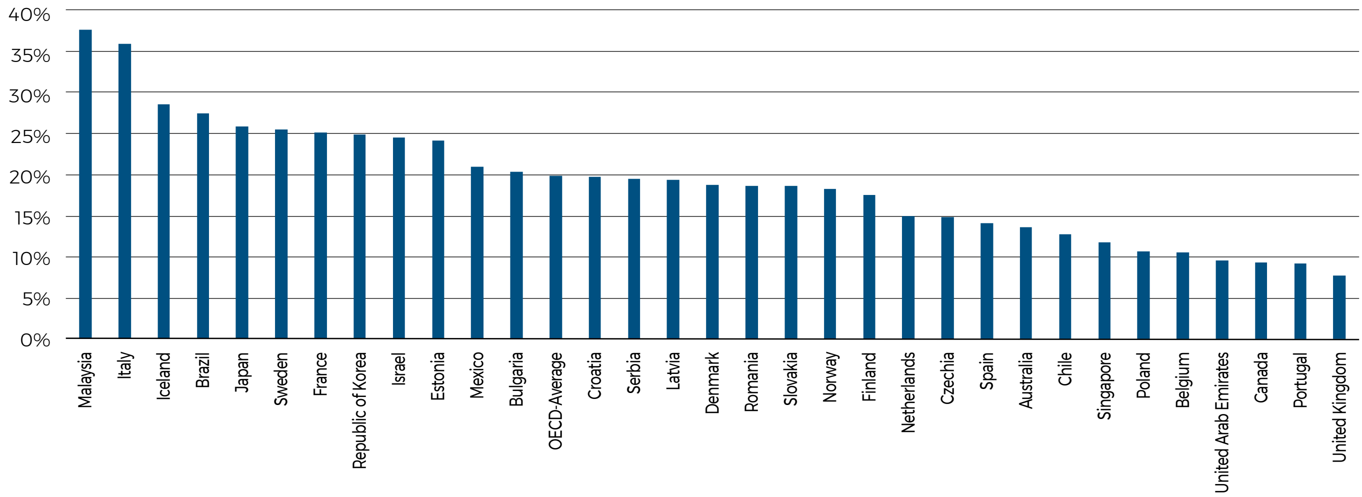
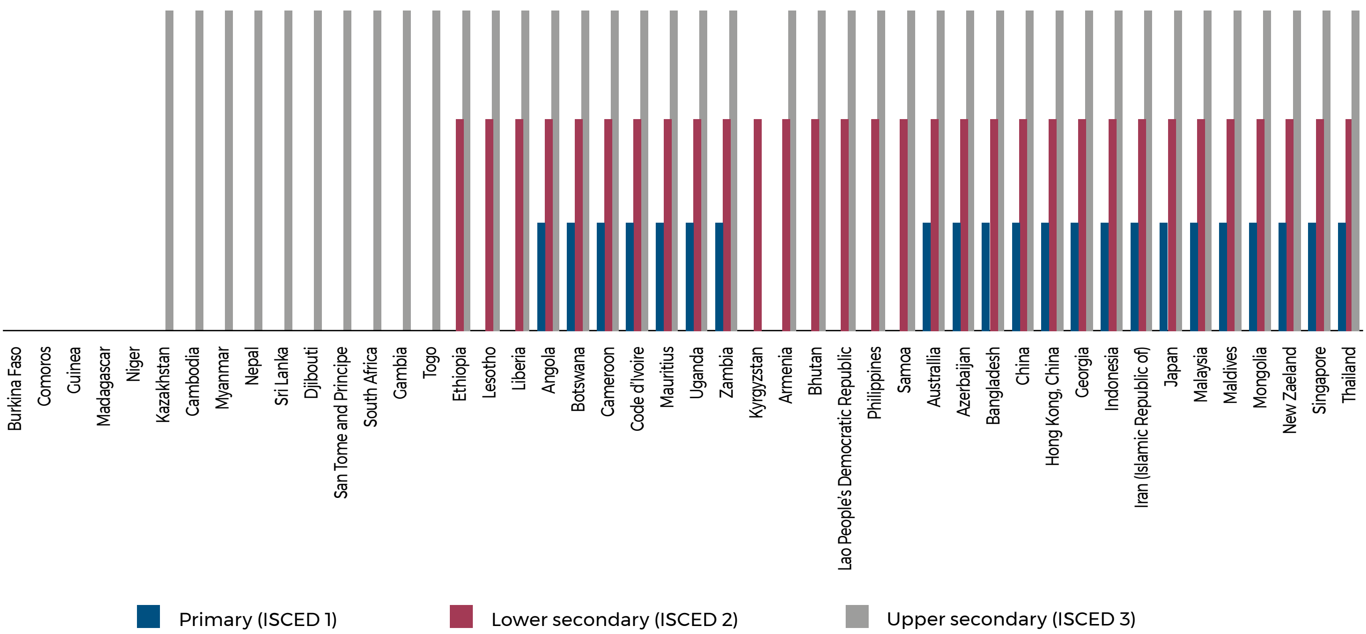


Figure 2-20 Teachers' need to develop their ICT skills for teaching (percent), 2013.
Source: OECD, 2015a.



Such achievements can only be made if the introduction of new modern educational methods involving digital tools is supported by teaching staff. Teachers must keep up with evolving technology, knowing what digital tools are best suited to their students and using these tools effectively in their classrooms. They must transform themselves into modern-thinking educators if they wish to continue inspiring young minds and equipping them with valuable digital skills for the future. According to the European Commission (2019), 6 out of 10 students are taught by teachers who engage in professional development activities on ICT in their own time. Teacher training in ICT is rarely compulsory. The shares of students taught by teachers that use ICT in 25 percent or more of their lessons range from 71 percent (ISCED 1) to 58 percent (ISCED 2) to 65 percent (ISCED 3), being highest in northern Europe. Teachers perceive insufficient numbers of tablets, laptops and PC desktop computers to be the major obstacle to their use of digital technologies in schools (European Commission, 2019).

Figure 2-21 Education levels (ISCED 1-3) with and objective or course in basic computer skills or computing in selected countries, various years.
Source: UIS Database, 2019.



Notes: Data for South Africa reflect 2011; data for Angola, Botswana, Togo and Zambia reflect 2012; data for Ethiopia, Gambia, Liberia and Mauritius reflect 2014.

The lack of digital tools and skills among teachers and students reflects on the need and request for ICT or computer subjects in schools. In EU-28, students rarely regularly engage in coding/programming activities: 79 percent of lower secondary school students and 76 percent of upper secondary school students never or almost never engage in coding or programming at school. Moreover, female students engage less often in coding than their male counterparts. On average, four out of five female students attending secondary schools never or almost never engage in coding (European Commission, 2019).

A similar situation is characterized for some OECD and developing countries. More than half of the countries in the latest data collection by UNESCO (2019) have integrated objectives or courses on basic computer skills or computing at primary, lower secondary and upper secondary levels of education, in some cases despite capacity to meet national curricula. For example, the available resources in developed countries such as Singapore, Japan and New Zealand are adequate to meet objectives, while Bangladesh faces challenges to universalize access to basic computer skills or computing in schools. In countries that do not have objectives or courses on basic computer skills (or computing) at all levels, emphasis is placed on secondary education. For instance, in Armenia, Bhutan, Lao PDR and the Philippines, basic computer skills and computing are emphasized beginning in lower secondary education, whereas in Cambodia, Myanmar, Nepal and Sri Lanka this occurs in upper secondary education. In Kyrgyzstan, a course in basic computer skills or computing occurs specifically at the lower secondary level (ADB, 2012).

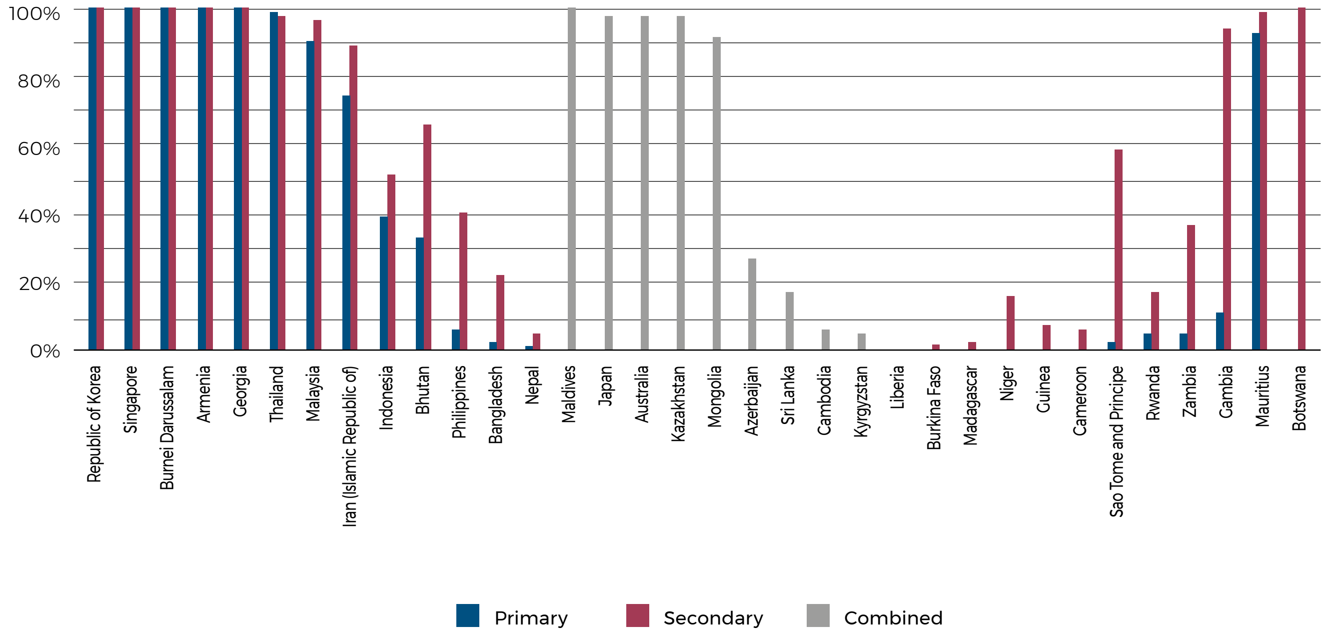
Despite some countries having more capacity to provide ICT in education than others, formal recommendations to integrate ICT in all subjects and at all levels exist in Armenia, Japan, Kazakhstan, Malaysia, the Philippines, Singapore, Sri Lanka and Thailand. In comparison, there are no formal recommendations for integrating ICT across curricula in Bhutan, Kyrgyzstan, Lao PDR and Nepal (ADB, 2012). However, in Nepal a computer science course is offered as an optional subject in secondary school (Nepal, 2012). In Kazakhstan, there is an ambitious programme to use e-learning packages in local languages in all subjects in all schools and to achieve 100 percent connectivity to eliminate the domestic digital divide (ADB, 2012), but this is likely to be very difficult. On one hand, for schools located in urban areas the ability to access online learning resources is a matter of fact. On the other, a journey into rural and remote areas, especially in developing and LDCs, is a completely different picture. Rural schools are largely left without access to the Internet, and the gap is also visible in developed countries.

Internet availability varies substantially within sub-Saharan Africa. For example, Internet availability is negligible in schools in Burkina Faso, Guinea, Liberia and Madagascar. Generally, Internet is more available in secondary schools than in primary schools, although remains scarce in 1 percent of combined secondary schools in Burkina Faso, 3 percent of secondary schools in Madagascar and 8 percent for secondary schools in Guinea, respectively. In Niger the proportions of lower and upper secondary schools with Internet are 2 percent and 14 percent, respectively. Despite progress achieved in decreasing learner-to-computer ratios in Rwanda, Internet connectivity remains low with 6 percent and 18 percent of primary and secondary schools, respectively, being connected. At the other end of the scale, in Mauritius 93 percent and 99 percent of primary and secondary schools are connected, respectively, while in Botswana all public secondary schools are connected to the Internet (UNESCO, 2015).

Varying levels of Internet connectivity exist in schools in Asia; it is still uncommon in many countries that lack electricity and basic telecommunication facilities in schools. Internet connectivity is particularly low in southwest Asia. For example, in Bangladesh and Nepal, 3 percent and 1 percent of primary schools and 22 percent and 6 percent of secondary schools, respectively, are connected to the Internet. Similarly, 17 percent of primary and secondary schools combined in Sri Lanka are connected, of which only 1 percent are connected by fixed broadband. In contrast, in the Maldives, where there is universal availability of electricity in schools, there is universal Internet connectivity, with 47 percent being broadband. Iran has also made progress in connecting its schools, with 74 percent and 89 percent of primary schools and secondary schools, respectively, being connected to the Internet, of which 54 percent and 74 percent are connected via fixed broadband. In central Asia, Internet connectivity gaps may be attributed to a number of additional factors, including difficult mountainous terrain, the unwillingness of Internet service providers (ISPs) to operate in unprofitable rural areas with low population density, and limited school budgets to pay for Internet services. In some cases where Internet connectivity was previously available, services have been discontinued because of funding cuts by external development partners (UNESCO, 2014).

The Internet is an important element in the educational process. Schools are a common location where students online access the Web, although very few online youth rely exclusively on their school for Web access. Use of the Internet at least once a week for learning purposes at EU-28 level is positive at minimum of 50 percent of all students. In most Nordic countries[21] (Iceland, Denmark

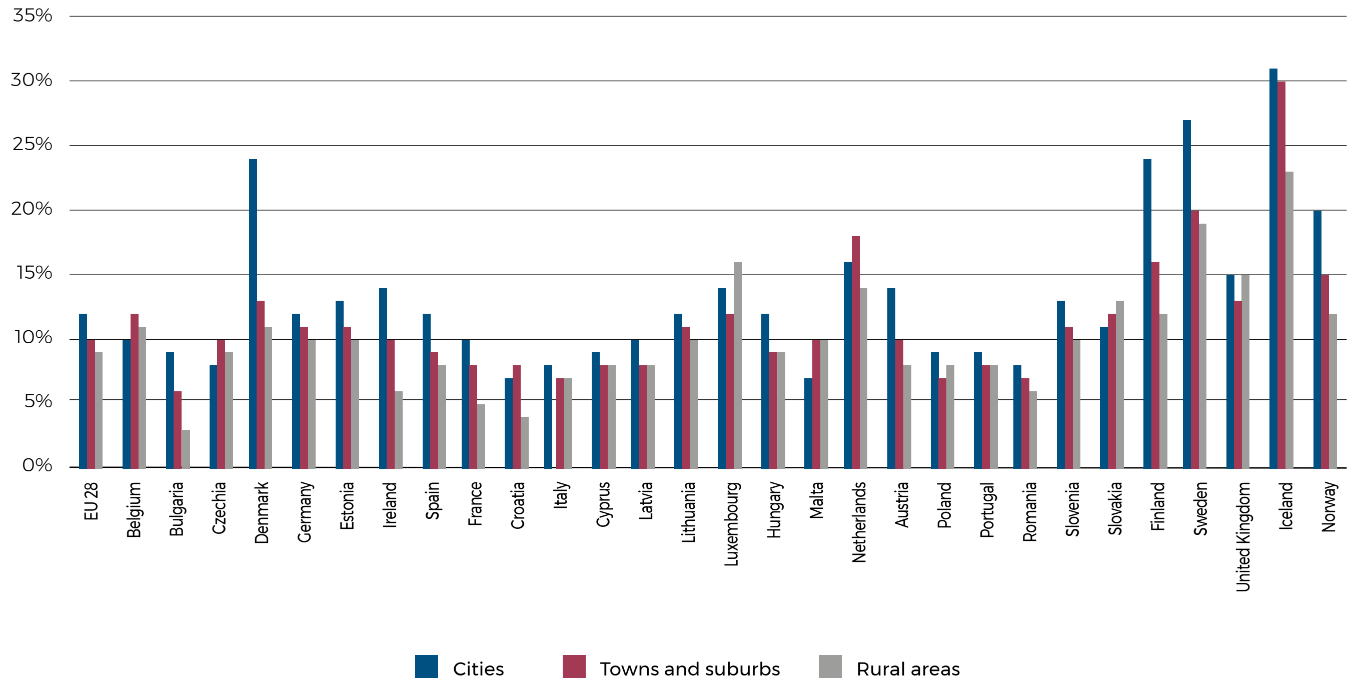
Figure 2-22 Proportion of educational institutions with Internet, primary, secondary and combined (primary and secondary) education, various years.
Source: UIS Database, 2019.



and Sweden), the percentage of students who use Internet at school for learning purposes is particularly high. However, these countries also have the highest gap between urban and rural areas. In EU-28, only 9 percent of students across all ISCED levels attend schools located in towns, suburbs and rural areas, which have access to high-speed Internet above 100 Mbps (European Commission, 2019).

Unlocking access to the Internet builds a degree of self-sufficiency for rural schools, allowing access to up-to-date curriculum education programmes and trusted e-learning resources, among many other benefits such as video and social media. Lack of infrastructure investment is the primary issue in rural communities, because of diminishing returns on government investment in regions with few subscribers. In addition, expensive costs for equipping rural schools with ICT tools and Internet, especially in LDCs and rural areas, are major obstacles to access. There also exists a gap in developed countries, as shown in Figure 2-23 among EU-28 countries. In EU-28, the average cost per student per year to equip

Figure 2-23 Internet access (above 100 Mbps) at place of education by degree of urbanization in EU-28, 2013.
Source: EUROSTAT, 2019.



and connect a classroom with advanced components ranges from 224€ to 536€. This includes costs for digital technology equipment, network requirements, professional development of teachers and access to content (European Commission, 2019). The cost of access to fixed wireless amounts to 8,000€/year (European Commission, 2019).

Such lack of infrastructure can result in an increase in the educational gap between rural and urban areas. Poor-quality/non-stimulating teaching in rural areas, lacking the differentiation to cater for different learning styles, can lead to early school leaving and lower chances of getting a job. Also, the low socio-economic backgrounds of the rural areas in which youth are living mean they are often working a high number of hours outside school, leaving little time for schoolwork and attendance. Taken together, this can lead to a lower percentage of education completed in rural areas compared with urban areas. Based on OECD (2018) data from 24 developing countries, 10.7 percent of rural youth complete secondary education and 10.5 percent tertiary education, compared with 33.3 percent urban youth completing secondary education and 18.1 percent tertiary education. This gap is clearly highlighted in rural areas of India, in which almost 4.5 percent of males and 2.2 percent of females complete an education level of graduation and above, compared with 17 percent of males and 13 percent of females in urban areas (CSO, 2018).

A widening education attendance gap by degree of urbanization is more significant in developing (15 percentage points difference) and developed countries (17 percentage points difference). As the income gap and wealth distribution are increasing in these economies, rural youth are most likely to decide to leave school early and migrate to urban areas looking for a better quality of life. At a country level, this difference is also visible in countries such as Ethiopia, Lao PDR, Cambodia, Peru, Bolivia, Nepal and Mongolia, having differences of 20 percentage points and above.

In 2015, the EU-28 share of people with tertiary education peaked at 27.9 percent in rural areas, compared with 48.1 percent in cities. At a country level, there are considerable differences between Member States. Mostly differences are recorded in the rural areas of Slovakia, Spain, Greece, Hungary, Estonia and highly in Romania and Bulgaria (almost 40 percentage points difference). By contrast, there were four western Member States, France, Germany, Belgium and Austria, as well as Malta, in which the early leavers' rate from education and training was higher among city-dwellers (Eurostat, 2018b).

Figure 2-24 Higher education attendance by degree of urbanization and economic development, various years.
Source: UNESCO Institute for Statistics, 2018.

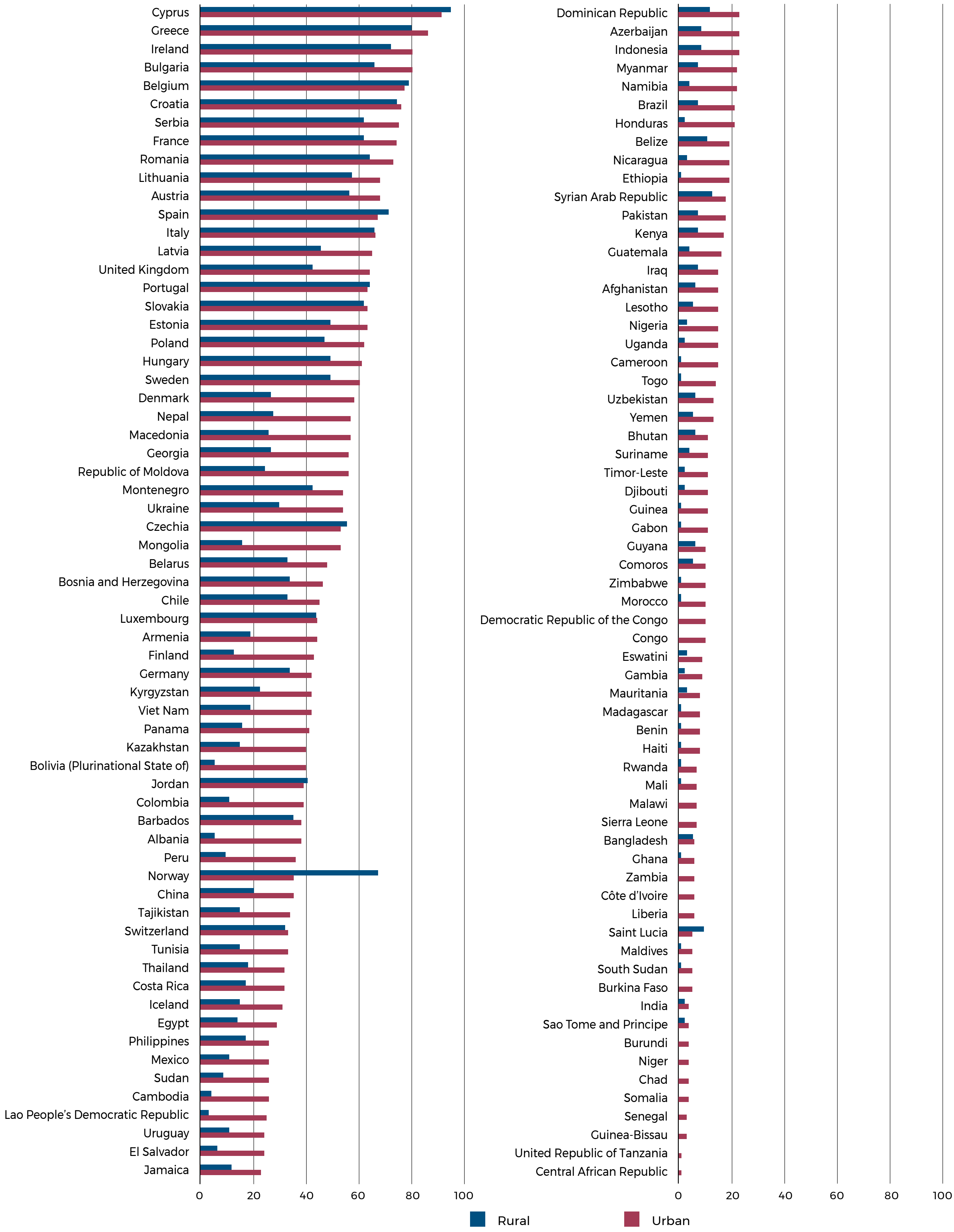
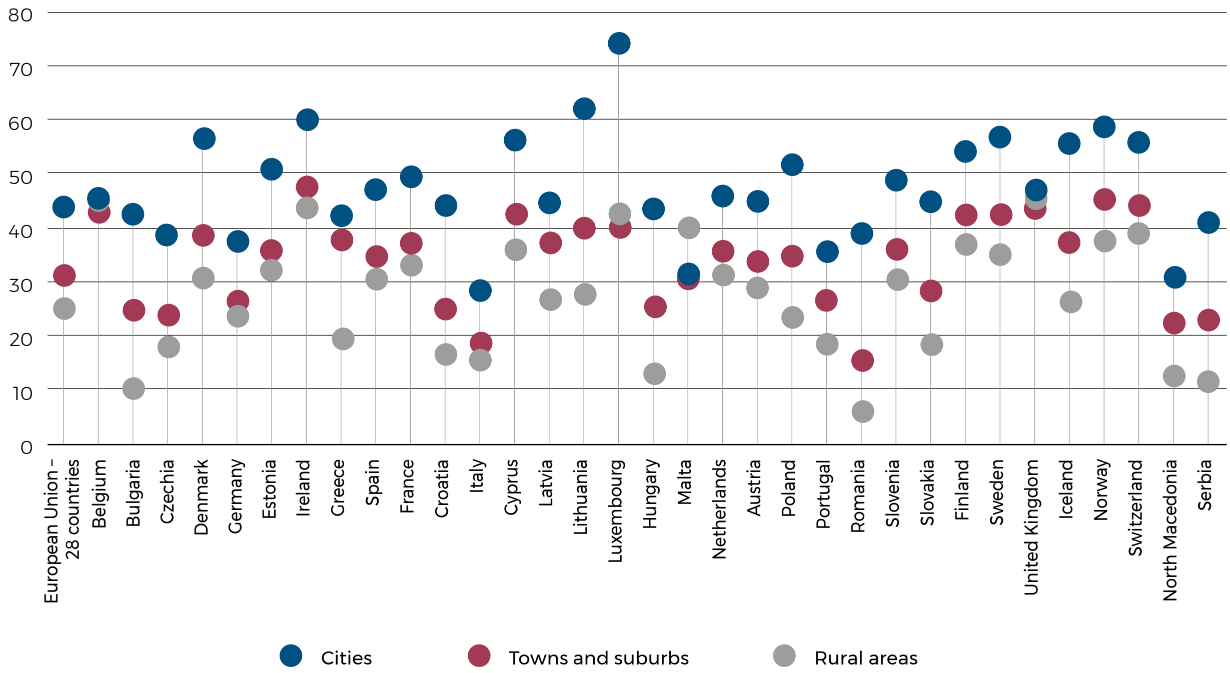


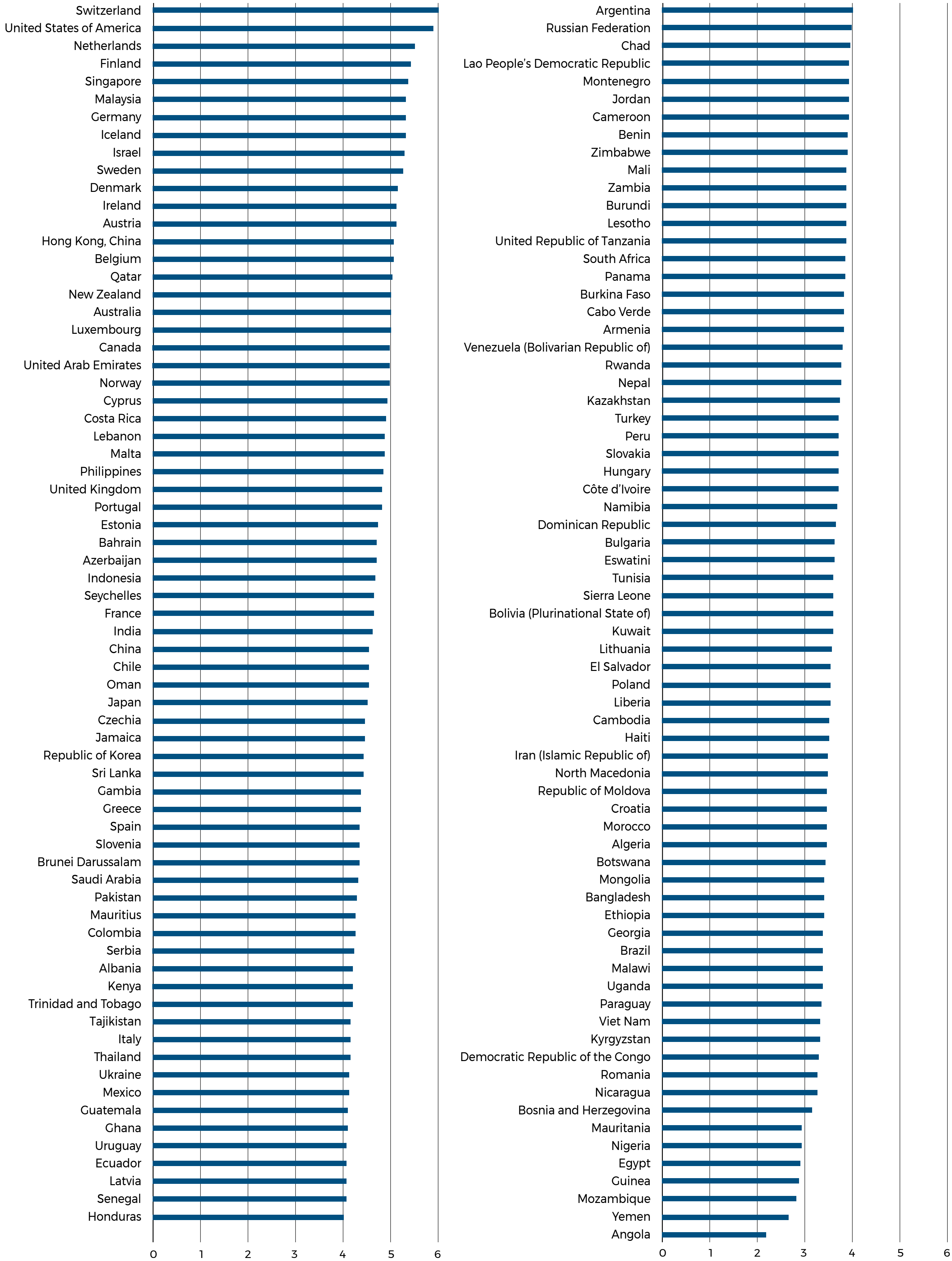
Figure 2-25 Share of people aged 20–54 with tertiary education (ISCED level 5-8) attainment, by degree of urbanization in EU-28, 2015.
Source: Eurostat, 2018b.



As a minimum, employers want graduates who are adept at using technology to connect, communicate and collaborate with workplace technology. A mismatch between potential employer expectations and how schools, colleges and universities prepare students for the future workforce has been well documented in academic studies, and continues to be an issue.

Yet with the right technology platform, solutions and industry partners, universities are starting to create next-generation learning environments that effectively prepare students for the future by offering access to the tools they need to prepare for the workplace while also providing a fulfilling learning experience (IMD and CISCO, 2015).

Figure 2-26 Skillset of university graduates (rate, 1–7 best), 2017.
Source: World Economic Forum, 2018.



2.2.3 EMPLOYMENT IN THE RURAL AREAS AND AGRIFOOD SECTOR

Over the next 15 years, about 1.6 billion people in low- and middle-income countries will reach working age. Creating jobs for a new generation of workers while sustaining and improving the quality of employment of the billions of people already working will be a significant challenge for all sectors, especially the agrifood sector (World Bank, 2017). When looking at the world's poor, approximately 78 percent of those living on less than US$2 per day live in rural areas, and 63 percent of the poor or 8 out of 10 are working in agriculture (Olinto *et al.*, 2013). In Latin America and the Caribbean, one out of five workers lives in rural areas characterized by greater vulnerable employment (ILO, 2016). Flourishing rural areas are vital to regional and national development. Yet, rural economies tend to face a wide range of challenges that are more likely to be overcome in urban areas.[22]

2.2.3.1 Gender and youth employment in rural areas

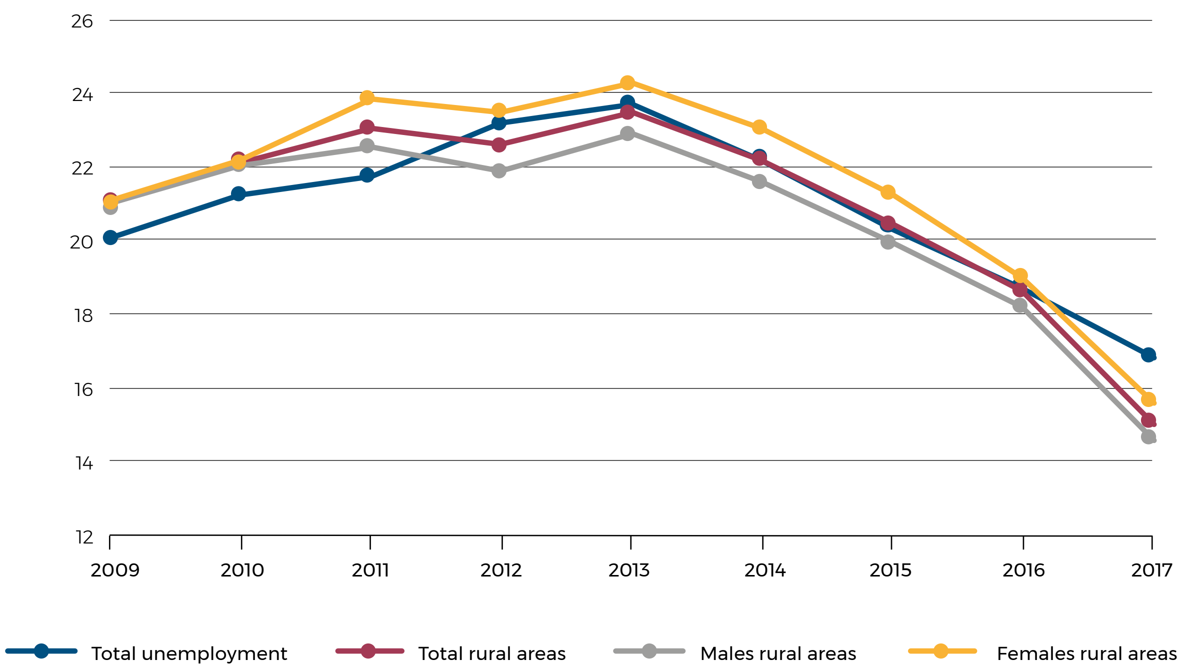
Today's generation of youth is the largest the world has ever known: 1.2 billion young people are between the ages of 15 and 24, and in the next 15 years around 600 million jobs will be needed to absorb entry of this youth generation into the labour market (Merotto, Weber and Reyes, 2019). In sub-Saharan Africa alone, more than 10 million new jobs per year will have to be created in rural areas in the next two decades to absorb the new entrants into the labour force. The great majority of those jobs will need to be in the private sector.

The population below the age of 24 accounts for the largest share of the population in almost all countries in sub-Saharan Africa, but also in many countries in South Asia, East Asia, Latin America, and the Middle East and North Africa (World Bank and IFAD, 2017). From a developing world point of view, most youth reside in South and East Asia, both of which are projected to be surpassed by sub-Saharan Africa (Filmer and Fox, 2014).

The latest ILO estimations show that in 2018, 21 percent of the world's youth were not in employment, education or training, while 37 percent were in employment and 42 percent were not in employment but in education or training. This means that over one-fifth of all youth in the world were passive job-seekers, not actively participating in the labour market by having a job or acquiring new skills in educational or training programmes, which prompts a call to urgent action to improve youth's access to decent jobs and capacity building (ILOSTAT, 2019). Emphasis should be on the rural youth, which constitute over half of the youth population in developing countries and will continue to increase in the next 35 years. Rural youth who are self-employed and contribute to family work constitute 49 percent of rural youth employment on average, and represent by far the dominant employment statuses in LDCs (OECD, 2018b).

In 2015, the share of young people (aged 18–24 years) in the EU-28 neither in employment nor in education or training stood at 15.8 percent. Taken by degree of urbanization, the rate for rural areas (17.9 percent)

Figure 2-27 Youth (15-24) unemployment in rural areas in EU-28 (percent), 2009–2017.
Source: Eurostat, 2018b.



was higher than that recorded for towns and suburbs (16.5 percent) or for cities (14.2 percent). The highest rate for rural areas was recorded in Bulgaria (40.9 percent), while Greece and Croatia both also recorded rates above 30.0 percent. The highest unemployment rates were recorded for rural areas (compared with cities) in Bulgaria, Lithuania and Slovakia in 2015. By contrast, the unemployment rates recorded in rural areas of Belgium, Greece and Austria were considerably lower than those recorded in cities, with differences of more than 5.0 percentage points. Very low unemployment rates (less than 4.0 percent) were recorded in rural areas of Austria, Germany and the United Kingdom (Eurostat, 2018b).

When looking into the share of youth not in employment, education or training separately for women and men, a striking gender pattern is revealed: over 30 percent of all young women in the world are not in employment, education, or training, compared to 13 percent of all young men (ILOSTAT, 2019). In other words, young women are more than twice as likely as young men to be jobless and not in education. This implies that young women face additional difficulties accessing the labour market, pursuing quality education or participating in vocational or skills training programmes. It could also suggest that women participate more in unpaid work. Indeed, whereas 44 percent of all young men in the world were in employment in 2018, only 29 percent of young women had a job, reflecting the strong challenges faced by women to enter the labour force (ILOSTAT, 2019). There are some significant disparities across regions regarding the severity of the problem. The situation is especially alarming in the Arab States, where 29 percent of all youth in the region were not in employment, education or training in 2018, compared to 23 percent in Asia and the Pacific region, 22 percent in Africa, 19 percent in the Americas and 14 percent in Europe and Central Asia. Youth in the Arab States are therefore twice as likely to be jobless and not in education or training as young people in Europe and Central Asia (ILOSTAT, 2019).

In particular, the low participation of women in the labour market is alarming: at present, only 31.9 percent of all women from rural areas have a job.[23] The gender participation gap is most pronounced in North Africa, the Arab States and Southeast Asia. In contrast, sub-Saharan Africa, North America, Europe and parts of Asia have lower than average gender participation gaps. Overall, the global gender gap in labour force participation stood at 27 percent in 2018, compared with 29.1 percent in 1990. Women and youth are disproportionately affected by underemployment, unemployment, precarious job situations and informal employment conditions. Their situations are often plagued by insecurity, poor working conditions, high workload, low productivity and low pay. In Europe, significant declines in gender participation gaps occurred across most countries between 1990 and 2018 including France, Germany, Italy, Spain and the United Kingdom. In North America, a similar decline occurred in Canada and the United States. In Latin America and the Caribbean, the reduction of the gender participation gap is also apparent. In Brazil, the gap halved from 41.2 percent to 20.4 percent, and in Mexico, the gap decreased by roughly 16 percentage points, but remains above the regional average. In Africa, the gender participation gap declined by approximately 8 percentage points and 10 percentage points in Nigeria and Ethiopia. In some of the world's most populous countries, such as China, India and the Russian Federation, there were either no substantial declines or slight increases in the gap (ILOSTAT, 2018).

2.2.3.2 Employment in agrifood sector

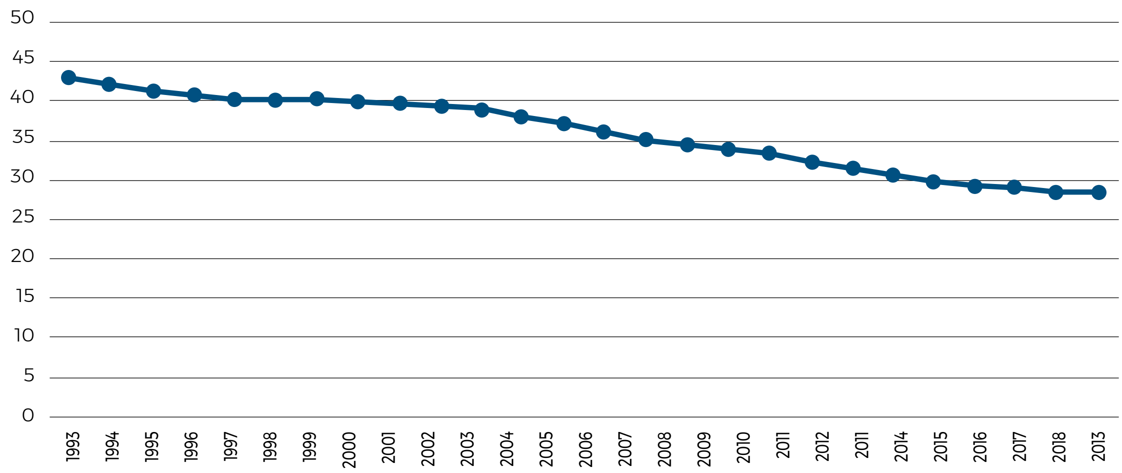
With 1.3 billion people employed in the sector, agriculture is the second greatest source of employment worldwide after services and it accounts for 28 percent of global employment. The agrifood sector currently accounts for 60 percent of total employment in sub-Saharan Africa, and almost 70 percent of total employment in low-income countries globally (ILOSTAT, 2019), and will continue to do so in the future. Jobs in the agrifood sector extend beyond agricultural production and account for a large share of the global economy's manufacturing and services sectors. As per capita incomes increase and eating patterns shift, the demand for jobs in these off-farm segments of the agrifood sector (processing, distribution, transportation, storage, retailing, preparation and restaurants) will increase (World Bank, 2017).

As countries develop, the share of the population working in agriculture is declining. Whereas more than two-thirds of the population in poor countries work in agriculture, less than 5 percent of the population does in rich countries (Figure 2-28).

The highest value was in Burundi (91.4 percent) and the lowest value was in Singapore (0.1 percent). Three-quarters of the labour force in a poor country like Madagascar are employed in agriculture, whereas in rich countries, such as Germany or the United Kingdom, only 1 in 100 people is employed in agriculture.

In Africa alone, 440 million young people will throng to the labour market by 2030. The majority live in rural areas and 90 percent are generating income from small-scale farming.[24] The projected employment share in farming (Ethiopia, Uganda, Tanzania, Mozambique, Malawi and Zambia) is projected to decrease from 75 percent to 61 percent, whereas the share of jobs in

Figure 2-28 Share of employment in agriculture in total employment (in percent), 1991–2018
Source: World Bank, 2019.[25]

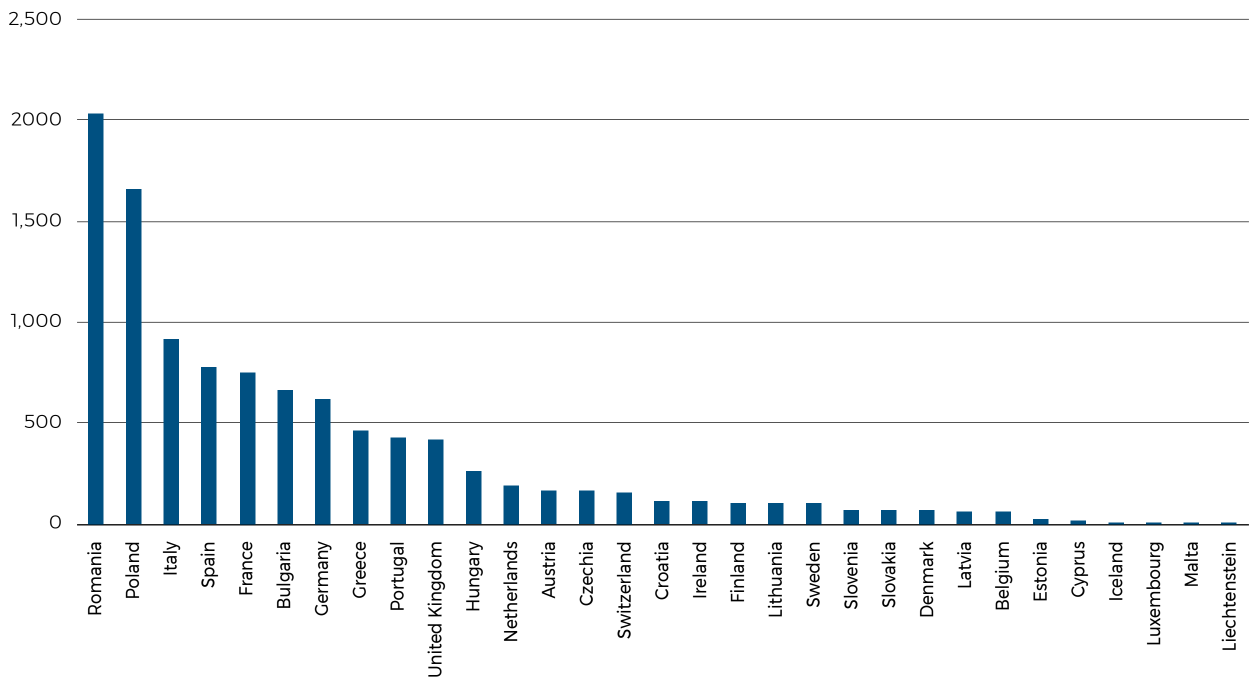


the broader agrifood sector (food manufacturing, food marketing, transportation, and food preparation), most of which will be in rural areas, is projected to increase from 8 percent to 12 percent over the same period (Tschirely *et al.*, 2015).

In EU-28, according to the national accounts, around 10 million people worked in agriculture in 2015, accounting for 4.4 percent of total employment. Almost three-quarters (72.8 percent) of the agricultural workforce in the EU-28 was concentrated in seven countries: Romania, Poland, Italy, France, Spain, Bulgaria and Germany (Eurostat, 2017a).

Employment in agriculture constituted more than 10 percent of total employment in four Member States: Romania (25.8 percent), Bulgaria (18.2 percent), Greece (11.0 percent) and Poland (11.0 percent). Very low shares below 2 percent, were reported in Germany (1.4 percent), Sweden (1.3 percent), Belgium (1.2 percent), Malta (1.2 percent), the United Kingdom (1.1 percent) and Luxembourg (0.8 percent) (Eurostat, 2017a).

Figure 2-29 Total employment in agricultural sector for EU-28, (thousand people) 2018.
Source: Eurostat, 2017a.



2.2.4 CONCLUSION

The main reasons for low education in rural areas include availability (density) of schools, distance to schools, classroom size, local budget available for education, whether or not families rely on child labour in the field. In addition, lack of digital infrastructure and support contributes to the lower percentage of youth in rural areas completing their education compared with those in urban areas, potentially leaving some rural youth illiterate. Those regions and LDCs that have higher gap in youth literacy between urban and rural areas also show a higher gender gap in their youth populations. Younger generations (aged 15–24 years) are progressively better educated than older generations, reflecting increased access to schooling; however, despite 60 percent of the countries and areas for which data are available having eradicated or almost eradicated illiteracy among youth, regional and gender disparities persist. Literacy is lowest in the rural areas of LDCs and higher among males than females. Improvements in female youth literacy are significantly greater than for men in most of the regions of the world.

Access to ICTs in LDCs is lagging behind developed countries, with the potential of widening the digital divide and disparities between the regions. There is an increased need for ICT or computer subjects in schools, as many schools in LDCs and developing countries do not offer basic computer skills or computing at primary, lower secondary and upper secondary levels of education. A similar lag is seen in terms of Internet access, particularly in rural schools.

2.3 Policies and programmes for enabling digital agriculture

2.3.1 INSTITUTIONAL SUPPORT AND MECHANISMS

Demand for digital transformation is partially being driven by government ICT strategies. Many countries are moving processes such as benefit payments, tax filing and passport applications online, and efforts are gearing up to digitize education, health and public services (McKinsey & Co., 2013). The agricultural sector is still lagging behind in the process, but grassroots initiatives are already present. Governments typically centre their digitization efforts on four capabilities: services, processes, decisions and data sharing (McKinsey & Co., 2016a). But not all countries have achieved success in the digitalization process, because designing and managing a digital government programme requires a high level of administrative capacity.[26] Developing countries, those most in need of digital government, are also those with the least capacity to manage the process.

Most of the Arab States, such as UAE, Qatar and Saudi Arabia, lead the way in terms of incorporating ICT within their governance strategies. Surprisingly, Rwanda is also among top countries, being the only country in Africa with an e-agriculture strategy. Brazil experienced a year-on-year average growth rate of –8.9 percent for the time period 2013–2016. Benin has the highest year-on-year average growth rate at 7.9 percent, whereas Libya has the lowest year-on-year average growth rate at –20 percent (WEF, 2019).

However, not all projects and initiatives are successful, especially those in LDCs and developing countries. Of the roughly 530 information technology projects funded by the World Bank from 1995 to 2015, 27 percent were evaluated as moderately unsatisfactory or worse. Given the complexity, it is not uncommon for many digital government projects to fail, and not just in the developing world. In fact, 30 percent of projects are total failures, with another 5060 percent partial failures, because of budget overruns and missed timing targets. Fewer than 20 percent of projects are considered a success. In 2016, government spending on technology worldwide was around US$430 billion, with a forecast of US$476 billion by 2020 (World Bank, 2016a).

Today, public expenditure on the Internet is approximately US$2 billion, which translates into just under US$3 per capita. If governments implement their national ICT strategies, move a number of services online, and introduce digital health and education initiatives, this could increase to US$60 billion, or US$50 per capita. This potential jump would exceed Brazil's current spending (US$32 per capita) but would remain significantly below levels in developed countries. To deliver on their strategies, governments may need to redirect some of their existing spending and generate additional funds for incremental expenditure (McKinsey & Co., 2013).

Figure 2-30 Importance of government on ICT (rate, 1–7 best), 2016.
Source: WEF, 2016.

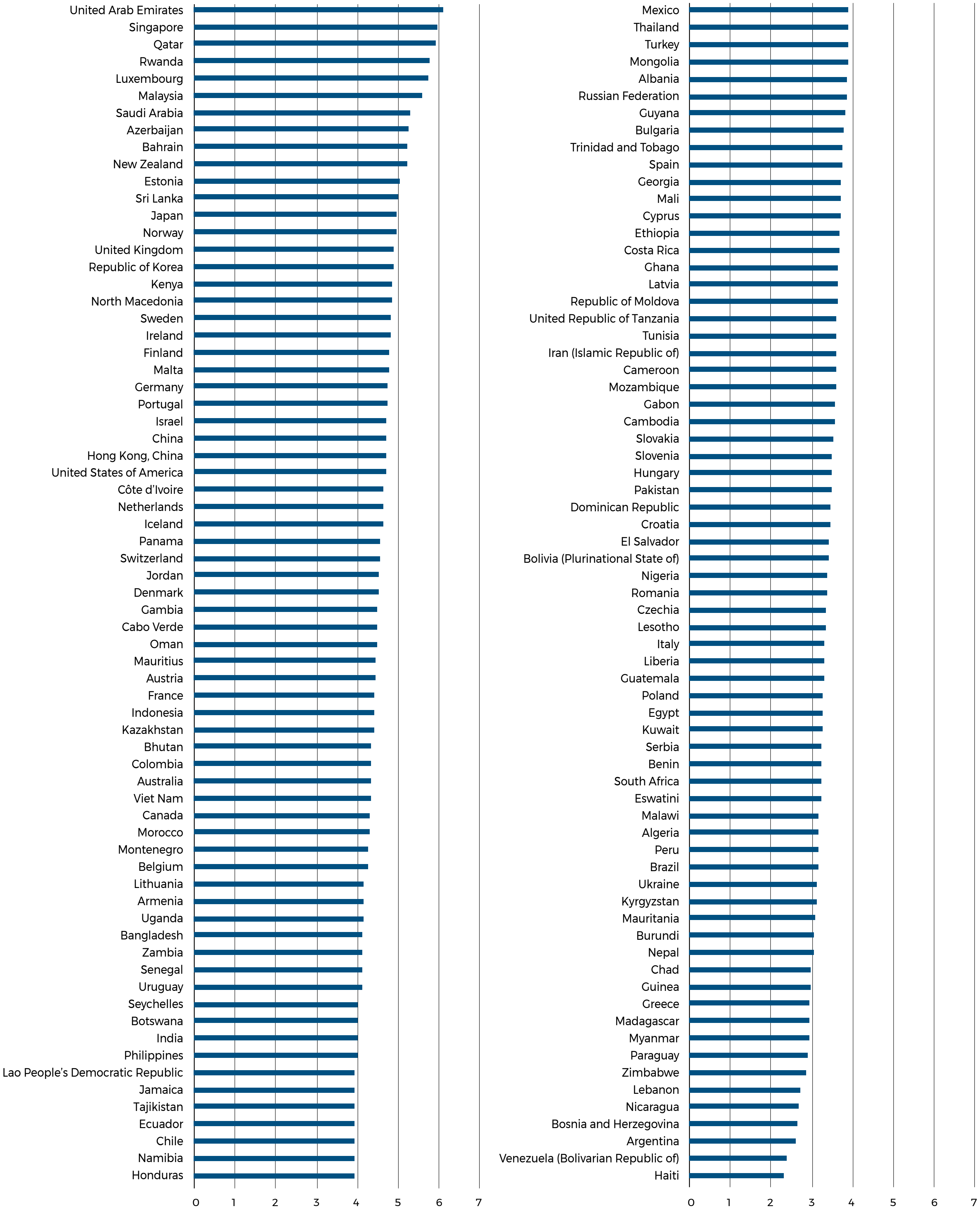
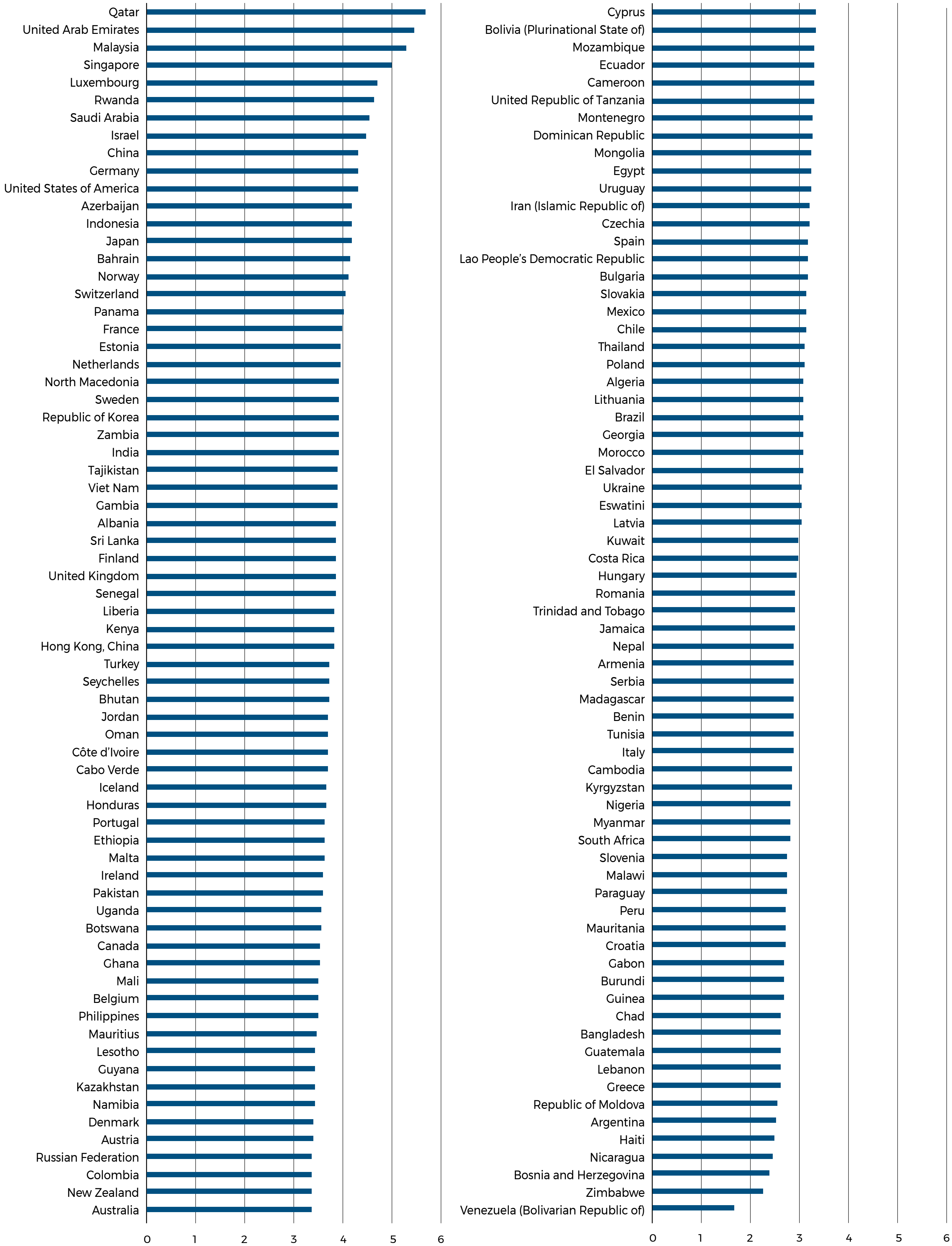


Figure 2-31 Government's procurement on advanced technology (rate, 1–7 best), 2016.

Source: WEF, 2016.



2.3.1.1 E-government services

E-government is the term given to use of ICTs in facilitating online registration, online service delivery, e-public services, e-revenue and one-stop service, or integration of all government services to citizens and businesses. For this purpose, the e-participation index aims to assesses the use of online services by governments to citizens ("e-information sharing"), interaction among different stakeholders ("e-consultation") and engagement in decision-making processes.[27] In developing countries, demand for e-services is lacking, both inside and outside the government. External demand from citizens is often silenced by popular cynicism about the public sector and by insufficient channels for communicating. As a result, not enough pressure for change is put on public sector leaders by citizens (World Bank, 2016a).

Given the progress of e-government, existing digital divides within countries must be bridged to allow everyone to take full advantage of the digital society (UN DESA, 2019). Countries in all regions are increasingly embracing innovation and using ICTs to deliver services and engage people in decision-making processes. One of the most important new trends is the advancement of people-driven services. This addresses the growing demand for more personalized services that react to individual needs, as well as people's aspiration to be more closely engaged in the design and delivery of services. These new demands are transforming the way the public sector operates (UN, 2016).

In 2010, a biometric-based national identity system called "Aadhaar" was launched in India. Within a few years, almost 95 percent of India's 1.25 billion people were registered in the system. In China, some provincial governments accept passport and visa applications through WeChat, a widely used mobile app. In developed countries ICT involvement into government processes and services is even more advanced. Estonia has a high-functioning digitalized platform that generates more than 30 transactions per citizen per month. The United Kingdom kicked off its digital transformation programme by digitizing 25 basic services, such as voter registration. Sweden's social-insurance agency began its digitization programme with five products that accounted for 60 percent of manual processing work and more than 80 percent of call-centre volume. In Denmark, more than 98 percent of the tasks involved in registering companies take place with no human effort. In the United Kingdom, the Web sites of all 24 ministerial departments and 331 other agencies and public bodies have been merged into a single Web site (McKinsey & Co., 2016b).

However, the process of implementing e-government is difficult and uptake among citizens can be slow. While Denmark, the number one ranked country in online service delivery in 2018, sees 89 percent of its citizens using e-services, many other countries are struggling. In Egypt, for example, uptake of e-services is just 2 percent (UN DESA, 2019). Just under half (48 percent) of individuals in the EU28 used the Internet for e-government purposes in 2016. Such activities were particularly common for people living across the regions of the Netherlands and the Nordic Member States, whereas interaction with e-government services was least common across the regions of Bulgaria, Italy and Romania (Eurostat, 2017b).

Figure 2-32 E-participation index, 2018.

Source: UN DESA, 2018.

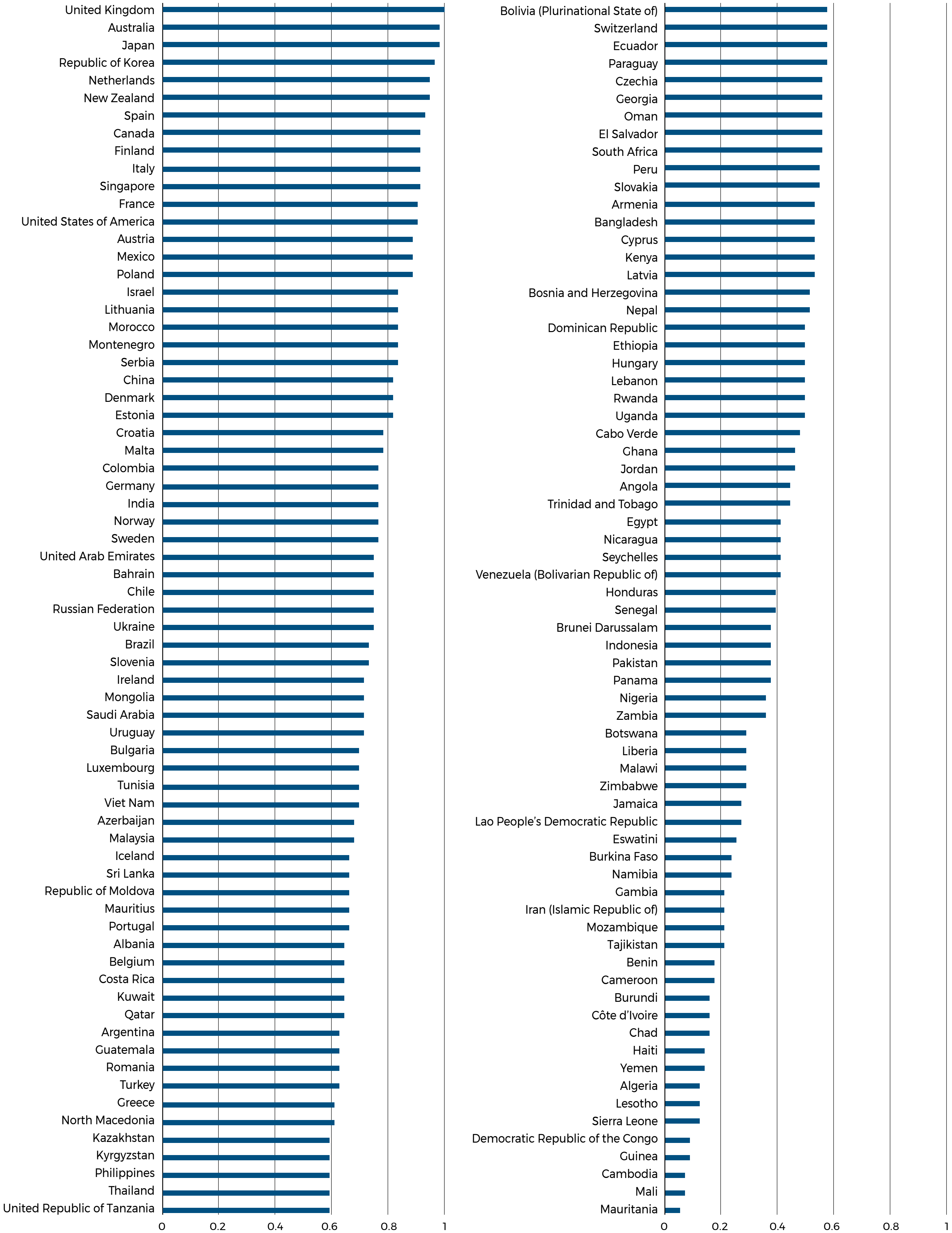


Figure 2-33 Government online service index, 2018.

Source: UN DESA, 2019.

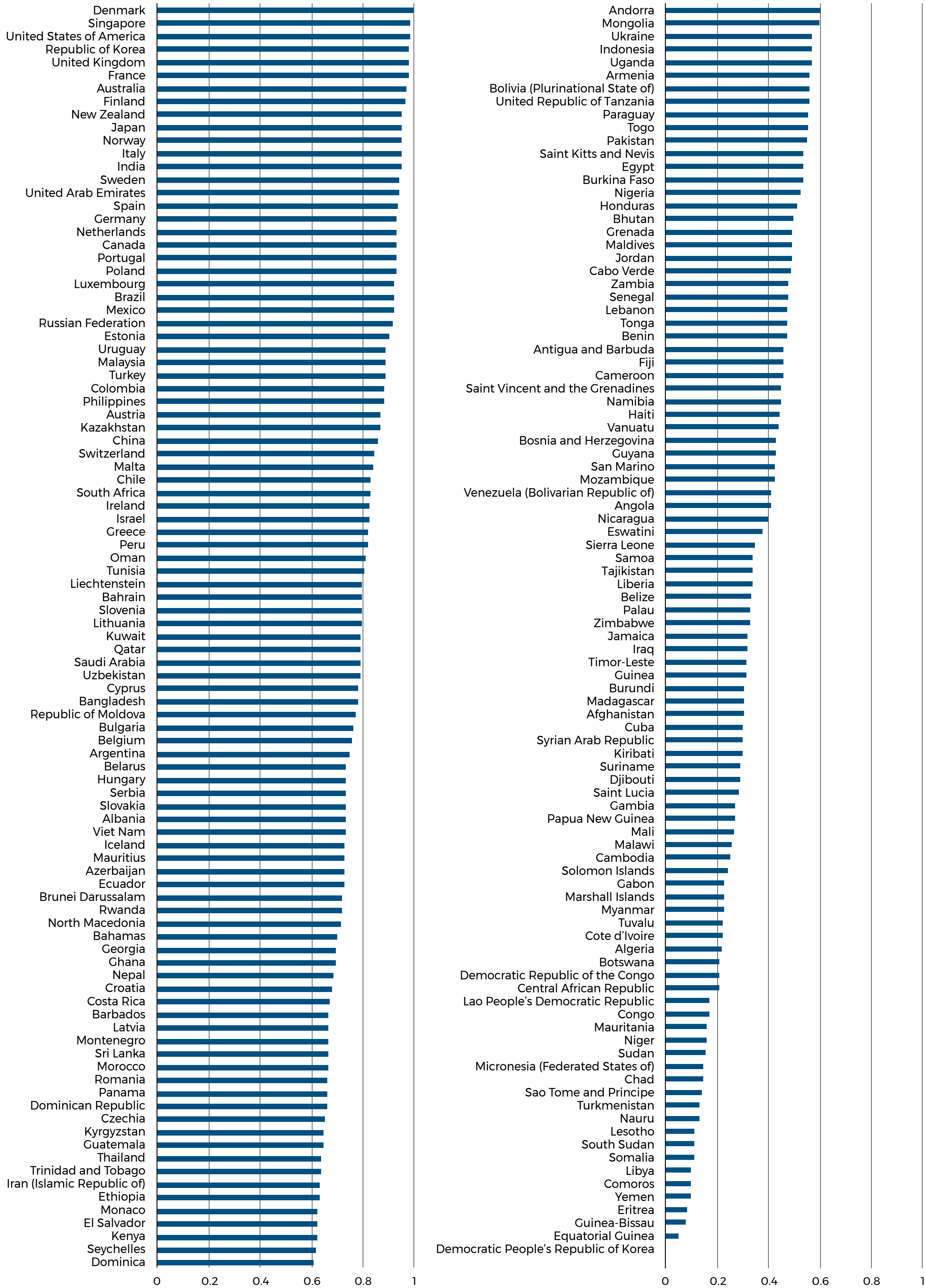
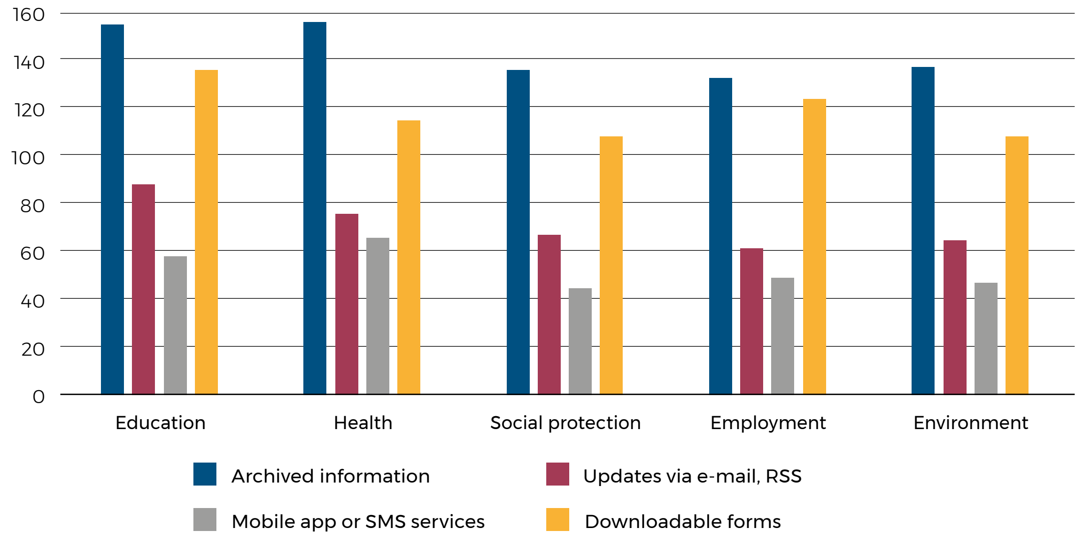


Figure 2-34 Types and numbers of government online services by sector, 2018.
Source: UN DESA, 2019.



Various government sectors are adopting and using digital technologies, the Internet, mobile phones and other tools, with the aims of collecting, storing, analysing and sharing information digitally. According to the UN 2018 survey, the number of countries providing online services through e-mails, SMS/RSS feed updates, mobile apps and downloadable forms has increased in all sectors. For instance, 176 countries are providing archived information online in the education sector compared with 154 in 2016. Similarly, mobile apps and SMS services in the health sector are offered in 70 countries compared with 65 in 2016 (UN DESA, 2019).

Services provided through mobile apps are growing fastest, at 52 percent, in the education, employment and environment sectors. Updates via e-mail and RSS have increased the most, at 62 percent, in the employment sector, followed by the environment sector, at 38 percent. Interestingly, fewer countries offer downloadable forms in the environment sector in 2018 compared with 2016.

The regional distribution of countries that provide online services via e-mail, SMS or RSS in the above-mentioned sectors is as follows: on average, 86 percent of countries in Europe, 71 percent in Asia, 59 percent in the Americas,

Figure 2-35 Governmental services provided via e-mail, SMS or RSS (percent of countries in each region), 2018.
Source: UN DESA, 2019.

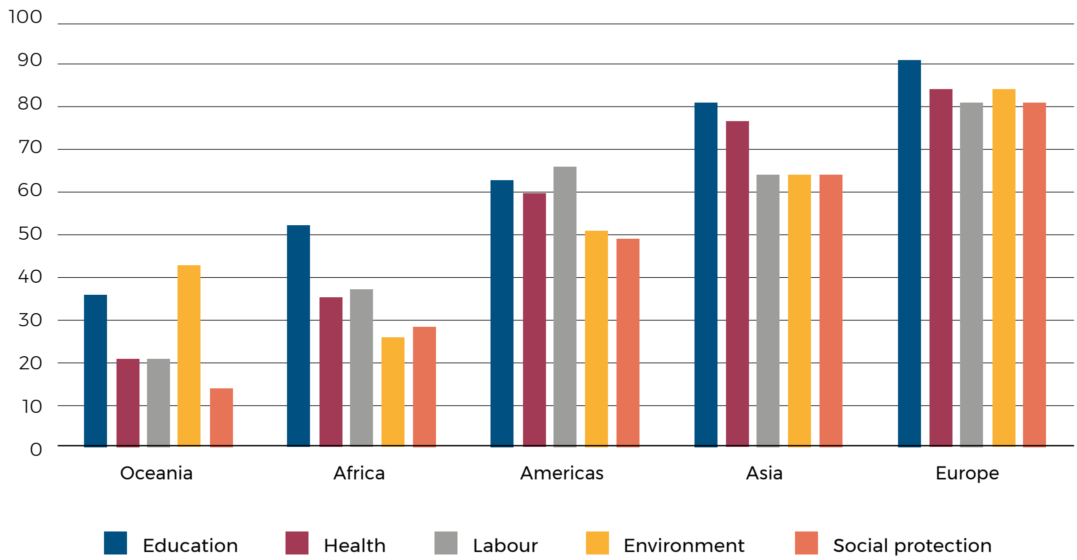
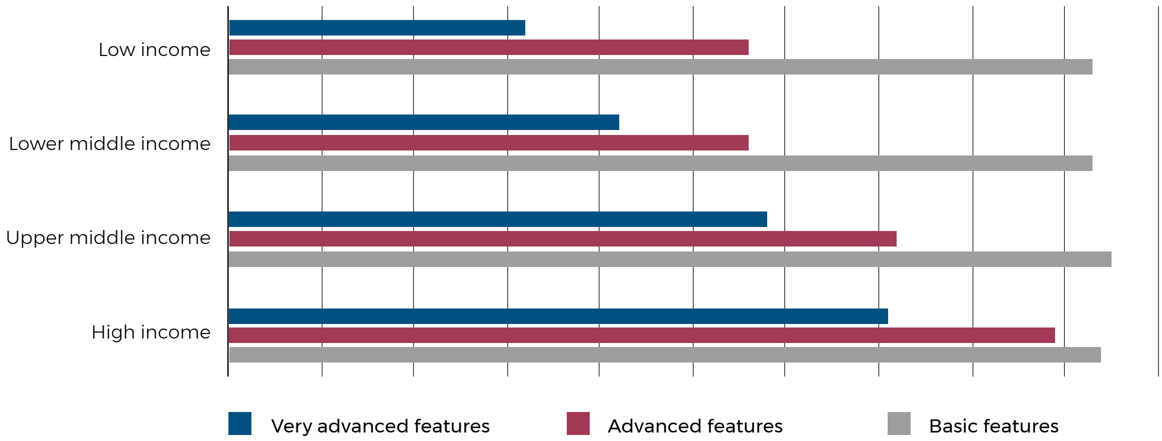


Figure 2-36 Availability of basic, advanced and very advanced services on national e-government portals by country income, 2018.
Source: UN DESA, 2019.



36 percent in Africa and 30 percent in Oceania. Most frequently, the online services offered are in education (64 percent on average), followed by health (55 percent), labour (54 percent), environment (54 percent) and social protection (47 percent).

Most government portals are now adopting the basic features covering ease of finding the portal, availability of basic searches, site map and "contact us" features, all of which are regularly updated. However, lower and low-income countries lag considerably behind in offering more advanced features such as help, frequently asked questions (FAQs), feedback options, links to one-stop-shop options, social media and automatic Web adaption to any device, as well as very advanced features for searching, availability of tutorials, help-desk, facilities to report unethical or corrupt behaviour, and ability to propose new open datasets (UN DESA, 2019).

2.3.1.2 E-agriculture services

Similar to the concept of e-government, e-agriculture services involve the conceptualization, design, development, evaluation and application of innovative ways of using ICTs in the rural domain, with a primary focus on food and agriculture. The broader concept of e-agriculture consists of technological application, facilitation, support of standards and norms, capacity building, education and extension (FAO, 2018). The most common e-agriculture services provided by governments are seed and fertilizer catalogues, online subsidies applications as well as microfinancing for agriculture, but not all governments provide those services.

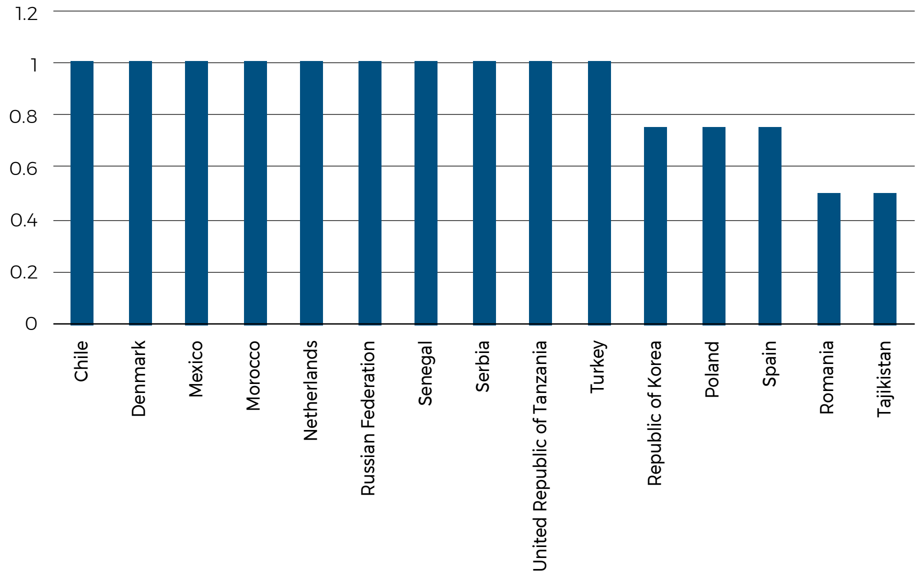
According to a World Bank survey (2017), which covered 62 countries, in 19 of these countries agribusinesses can submit online application forms for issue of phytosanitary certificates, either by e-mail or via an online portal. In 33 countries, applications continue to be submitted in hard copy form to the nearest plant protection office or electronic systems are not currently working. Only in a few such as Chile, Kenya, Korea and the Netherlands, can phytosanitary certificates be generated, issued and sent in electronic form (World Bank, 2017).

Registering new fertilizer products is good practice, because it ensures that a country has control over the fertilizers used within its borders (EBA World Bank, 2017). Also, enabling online access to catalogues can better inform farmers and retailers on the list of available and registered fertilizers in the country as well as make easier work for extensionists, who know what is in place and what to recommend to farmers. However, only few LDCs and developing countries have such online public catalogues, including Bangladesh, Columbia, Georgia, India, Kenya, Mozambique, the Philippines, Turkey and Viet Nam.

Tracking plant disease on governmental Web sites is less often applied in developing countries. Some high-income OECD countries, and recently Mexico and Turkey, have progressed in terms of available information on plant pest and disease. In sub-Saharan Africa, 7 of 21 surveyed countries did not have a clearly designated government agency to conduct pest surveillance and only Senegal and Tanzania have a publicly available database with information on plant pests and diseases (EBA World Bank, 2017).

To apply appropriate inputs, farmers must have access to appropriate data, but they can only make use of the data if they can follow the recommendations with the appropriate inputs, and vice versa. But availability of inputs is not always given, especially in LDCs and developing countries. For instance, in Kenya, 35 percent of smallholder farmers have access to improved seed, in Tanzania only 15 percent.[28]

Figure 2-37 Obtaining information on plant pest and disease from governmental Web site, 2017.
Source: EBA World Bank, 2017.



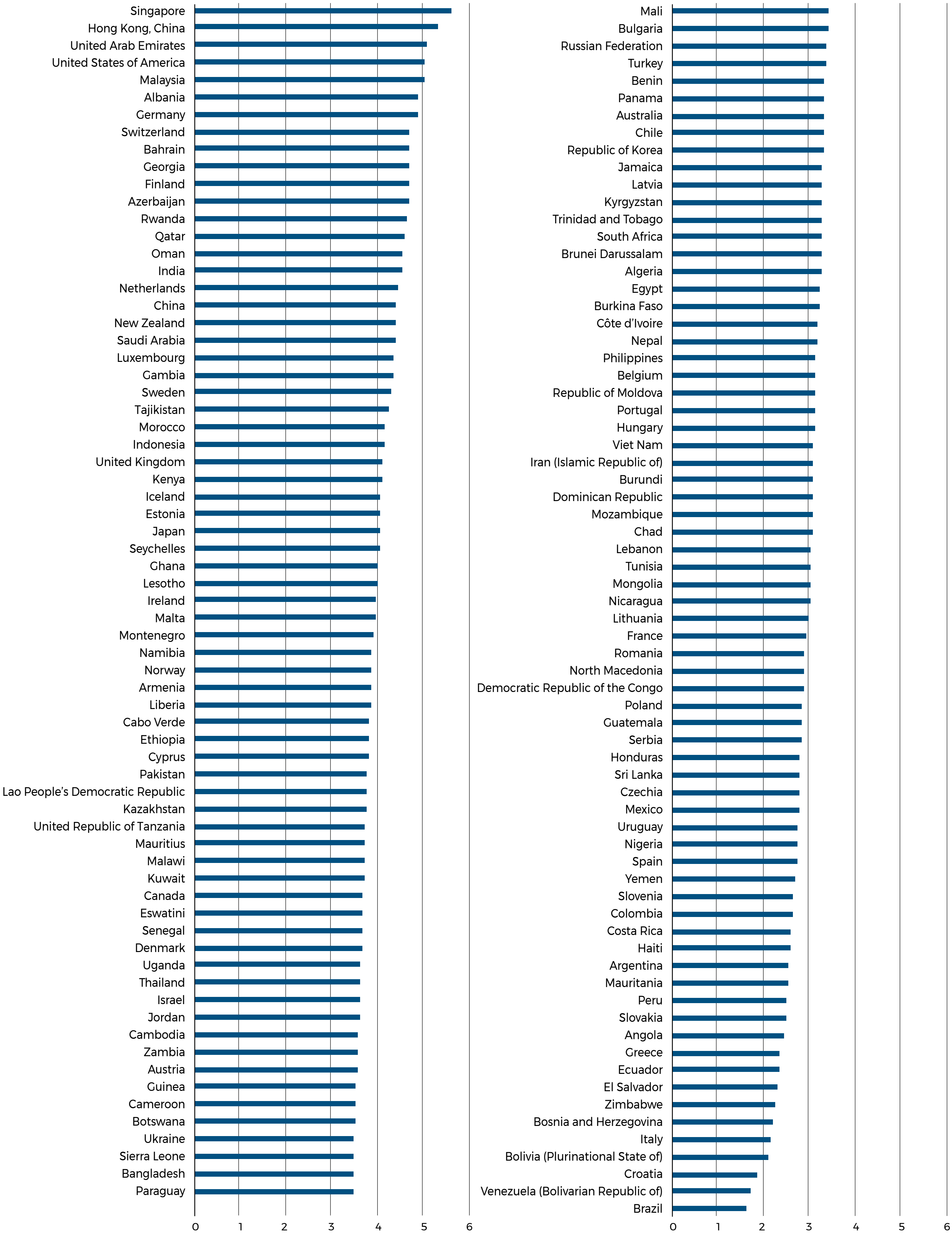
2.3.1.3 Doing agribusiness initiatives

"Doing Business" advocates for both regulatory quality and efficiency. It is important to have effective rules in place that are easy to follow and understand. To realize economic gains, reduce corruption and encourage small medium enterprize SMEs to flourish, unnecessary red tape should be eliminated. However, specific safeguards must be put in place to ensure high-quality business regulatory processes; efficiency alone is not enough for regulation to function well (World Bank, 2019).

Countries' regulatory quality is associated with economic growth (Eifert, 2009; Divanbeigi and Ramalho, 2015) and levels of development (Acemoglu *et al.*, 2003) Indeed, the 10 top economies in the ease of doing business ranking from the World Bank (2019) share common features of regulatory efficiency and quality, including mandatory inspections, automated tools used by distribution utilities to restore service during power outages, strong safeguards available to creditors in insolvency proceedings and automated specialized commercial courts (World Bank, 2019).

Those countries highly ranked on "Doing Business" have better agribusiness regulations as measured by EBA World Bank (2017). For example, as a result of regional integration in the European Union (EU), companies do not have to obtain any additional agriculture-specific documents when trading products between EU Member States. In East Asia and the Pacific, South Asia and sub-

Figure 2-38 Burden of government regulation (rate, 1–7 best), 2018.
Source: World Economic Forum, 2019.



Saharan Africa, however, at least two documents are required for each shipment. It is most time-consuming to complete the process in sub-Saharan African countries, taking 6 days on average, and the documents are most expensive in South Asia and sub-Saharan Africa, costing 2.5 percent income per capita on average (EBA World Bank, 2017).

Of the 62 countries studied by EBA World Bank (2017), 48 legally require fertilizer products to be registered before they can be imported and sold in the country. Some countries, such as those in the EU, perform well on the fertilizer registration indicator because they have strong legal frameworks in place and there is a low-cost process to register fertilizer products, which is streamlined and efficient. However, many other countries lag behind despite a strong legal framework, either because businesses do not register fertilizer products in practice or because the registration process is so onerous as to discourage the registration of new fertilizer products altogether (EBA World Bank, 2017). Bosnia and Herzegovina and Serbia are among the top five countries globally in the fertilizer area, because of best practice regulation on registration and quality control. The fertilizer registration process takes about 1 month in both countries, and costs only 0.5 percent and 5.3 percent income per capita, respectively.

In Africa the role and goal of government is to create an enabling environment in which agricultural businesses can flourish and contribute to the economy, infrastructure and social development in the areas in which they operate; however, such an enabling environment is lacking. Figure 2-39 illustrates perceptions of the level of support that some African governments provide to agribusinesses.

Nigeria has forged ahead to use digital technology to revamp systems for delivering fertilizer subsidies. Its "e-wallet" programme has already achieved major savings, eliminated opportunities for corruption, expanded the number of farmers served and far exceeded its production targets. Internet technology can drive up to US$3 billion in annual productivity gains in the sector (McKinsey & Co., 2013). In India, the eBiz platform has integrated several processes across (government) departments to make the process of incorporating a company simpler, reducing the time taken to register a company from almost 10 days to 5 days.

Spain has in place the highest number of the non-discriminatory measures in agriculture. Out of the 29 good practices that EBA covered, more than 27 are included in its agricultural laws and regulations, with only a few legal obstacles that prevent domestic or small-sized companies from engaging in operations in the agriculture sector. Sub-Saharan African countries including Tanzania and Zambia are also among the top performers in this area. For example, there is no minimum capital requirement to establish a producer organization in Tanzania, and Zambia grants transport, backhauling, triangular and transit rights to foreign transport companies. On the other hand, countries such as Haiti, Malaysia and Myanmar have greater potential for improvement. For example, in Malaysia, foreign companies are not yet allowed to obtain a trucking licence, and in Haiti, non-bank businesses cannot issue e-money (EBA World Bank, 2017).

Figure 2-39 Role of government in supporting African agribusinesses, 2017.
Source: PwC, 2016.

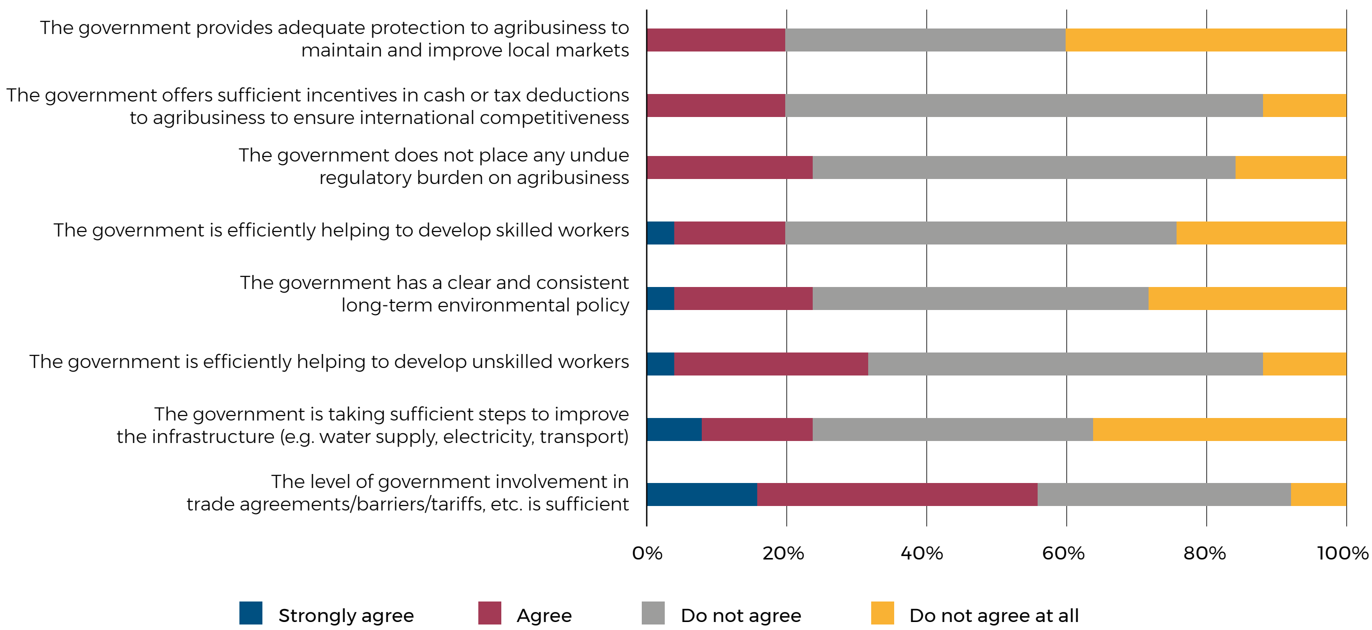
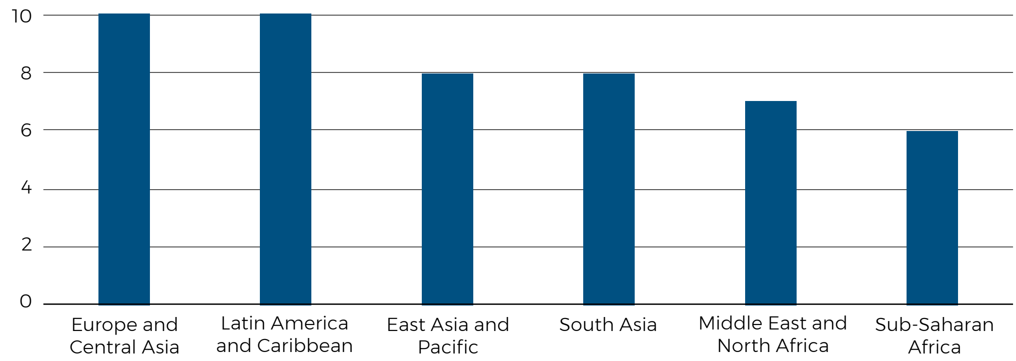


Figure 2-40 Average number of good practices related to access to information, 2017.
Source: EBA World Bank Database, 2017.



On average, OECD high-income countries have the highest number of good practices related to access to regulatory information such as water resource monitoring results, regulated quarantine pest lists and official fee schedules for seed certification. In other regions, greater effort is needed to make regulatory information more accessible to the public. For example, in sub-Saharan Africa and the Middle East and North Africa, where 24 countries were studied, half of the countries' laws did not specify a method for calculating the water abstraction charge, and only Kenya and Mozambique currently have online fertilizer catalogues.

2.3.2 POLICY REGULATION AND FRAMEWORKS

Government policy affecting ICTs can have a major effect on achieving the SDGs. Key areas have been defined in which governments need to establish legal, regulatory, budgetary and policy frameworks to ensure that ICTs make an optimal contribution to sustainable development.[29] In many countries, policies or regulations hinder the introduction of digital technology, or simply stop it. Often such regulations pre-exist the digital age, and, without reform, remain as blockers. In other cases, governments introduce new rules which act as blockers. For example, Indonesia has a stated target to provide digital literacy to its population, yet there is no specific programme to encourage farmers to use digital technologies.

2.3.2.1 MNOs, licences and monopoly

Traditionally, a licensing regime has been applied to authorize mobile operators to provide telecommunication services; however, as a result of rapid technological development and the convergence of networks and services, a more open authorization framework is now considered to be a good practice. Analysing countries based on their economic development, it is unclear whether more developed countries have more open or closed authorization. MNO regulations and policies are different from country to country, as well as from region to region. Although, some developing countries are more open and push market liberation, because most of their territory is predominantly rural and remote, MNOs are not willing to invest in network coverage or broadband. Instead, they are moving to the concept of "tower" companies, wherein the main core of their infrastructure is outsourced to private companies. There are many successful examples of this, especially in India,[30] where competition is high and prices of telecom services rapidly decreased.

Efficient spectrum management, by the government or by MNO's "tower" concept, will aid rollout of networks to rural and remote areas, because of digital dividend bands, reduced deployment costs and intensity of competitors providing these services (EBA World Bank, 2017).

There remains a need in most countries to modernize regulatory frameworks for the mobile sector. Authorities should be looking at two key areas for review and reform: firstly, regulatory frameworks should be reviewed and updated to promote market dynamism, competition and consumer welfare, while discarding legacy rules that are no longer relevant in the context of the digital ecosystem. Secondly, governments should reduce the sector-specific tax burden to encourage investment in new technologies. By setting the right regulatory context, governments can create incentives for technological innovation and investment that would benefit all of society (GSMA, 2019).

As for broadband policies, many other policies and regulations on ICTs and MNOs do not correlate with the level of economic development of given country. For example, Somalia, with its unregulated telecoms market, has higher mobile density than Ethiopia, which maintains a government monopoly.

Vibrant competition in mobile and fixed access should increase usage rates, whereas less competition can certainly hold this back. In Latin America, for example, the top priority for telecoms operators is to maximize average revenue per user (ARPU), which means that

Figure 2-41 Broadband policies per country, 2018.
Source: Alliance for Affordable Internet, 2018.

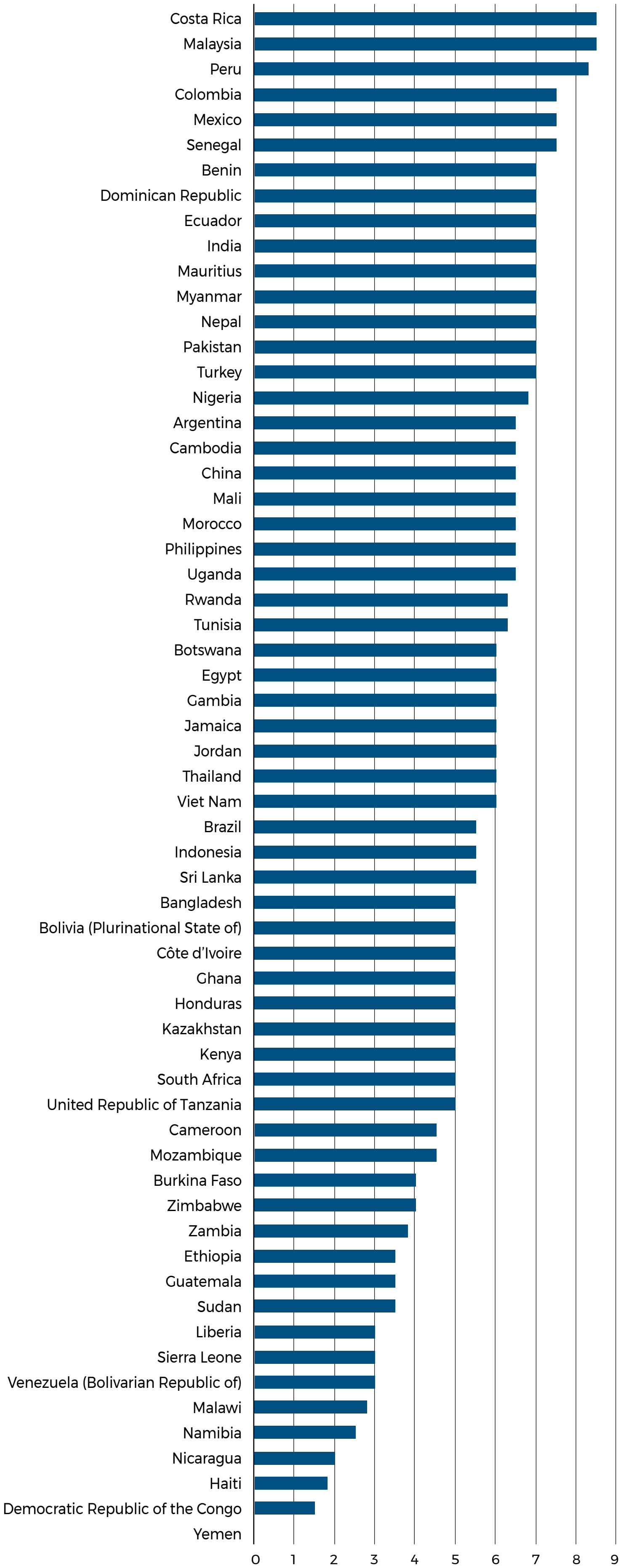
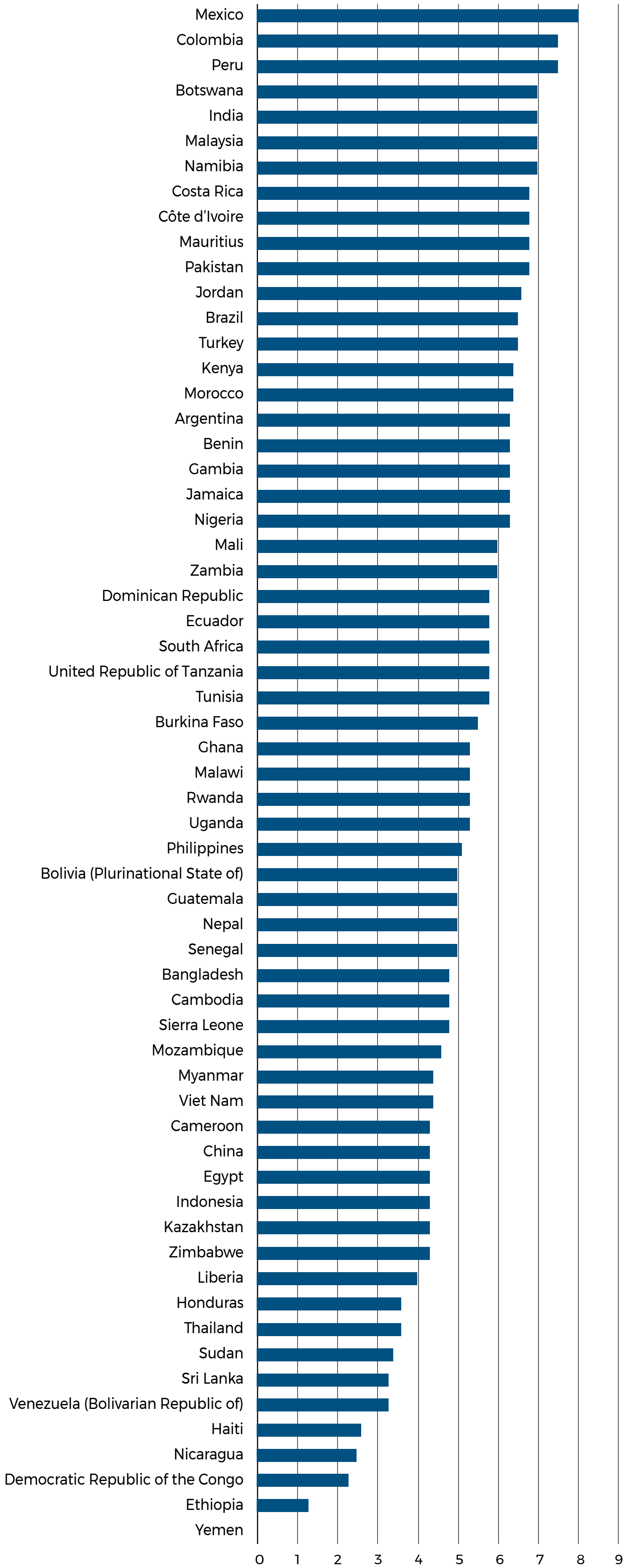


Figure 2-42 Policy and regulation for competition in the ICT sector and MNOs, 2018.
Source: Alliance for Affordable Internet, 2018.



services are relatively expensive and are therefore consumed by lower numbers of users, especially compared with their South Asian counterparts who have opted for a model based on increasing user numbers and usage. One factor is the lack of competition in many parts of Latin America, where telecoms provision is often a monopoly or a duopoly, whereas in much of South Asia there is competition between several providers (*The Economist*, 2012).

2.3.2.2 Data protection and privacy

Governments collect large amounts of personal information for civil registries, social security, housing records and tax purposes. The collection of biometric data for passport issuance for identification purposes adds to a wealth of personal data that is collected, stored and managed by states through ICTs to increase efficiency and reduce bureaucracy. Often, governments face challenges to ensure a proper balance between the privacy rights of their citizens and national security. With the rapid expansion of software and Web search engine companies, social network platforms and e-commerce, users disclose personal information that, although making service delivery and social networking more efficient and relevant, results in a massive amount of identifiable information that is owned, controlled and used by digital service providers (FAO, 2017). A challenge for privacy is the expanding use of Big Data – data that are subject to complex automated discriminatory technologies – that can classify users and customers into categories according to their preferences, income, ethnicity, political views and other sensitive characteristics. The "Internet of things" that connects devices to the Internet, can also result in detailed user profiles and poses similar privacy challenges (FAO, 2017).

Many states have rules to ensure that personal data are protected – about 107 countries have privacy laws in place as of 2014, with half of these being developing countries (UNCTAD, 2015). These legal frameworks define the purposes for which personal data can be collected legitimately and establish rules for proper management and protection from misuse. For example, in the EU, the Directive on Privacy and Electronic Communications (ePrivacy Directive) builds on the EU telecoms and data protection frameworks to ensure that all communications over public networks maintain respect for fundamental rights, in particular a high level of privacy, regardless of the technology used. This Directive was last updated in 2009 to provide clearer rules on customers' rights to privacy.[31]

In 2013, the OECD published its Guidelines on the Protection of Privacy and Transborder Flows of Personal Data, revising work originally carried out in the 1980s to enhance privacy protection in a data-driven economy. The Africa Union Convention on Cybersecurity and Personal Data Protection provides for establishing legal frameworks aimed at strengthening fundamental rights and public freedoms, particularly concerning the protection of data. At the international level, in 2015 the United Nations Assembly adopted a resolution on the right to privacy in the digital age and appointed a special rapporteur on the right to privacy to ensure its promotion and protection, including in connection with the challenges arising from new technologies.[32]

The UN Global Pulse, an innovation initiative of the United Nations Secretary-General to harness safely and responsibly the potential of Big Data for sustainable development and humanitarian action, has developed a set of Privacy Principles in consultation with its UN Data Privacy Advisory Group. The Group comprises experts from the public and private sectors, academia and civil society, and provides a forum for continuous dialogue on critical topics related to data protection and privacy and on how privacy-protected analysis of Big Data can contribute to sustainable development and humanitarian action.[33] Also, the United Nations System Organizations set out principles as a basic framework for the processing of "personal data".[34] The issue of protecting personal information collected, stored and managed by ICTs becomes more complex, as personal data are being processed and transferred on a regular basis across national borders. There is no international binding agreement on cross-border digital data flows and in many countries although data protection and privacy laws are based on a common set of principles, they are locally adapted and often do not comply with each other (World Bank, 2016a).

Instead, digital data transfers, as well as digital trade, are often governed by bilateral, multilateral or plurilateral agreements. For example, The Asia-Pacific Economic Cooperation initiated the Crossborder Privacy Enforcement Arrangement Privacy Framework to underpin the free flow of information in Asia and the Pacific region to improve consumer confidence and ensure the growth of electronic commerce.[35] The US and the EU initiated a framework for transatlantic data flows – especially personal data of European consumers – in 2000 (Safe Harbor Agreement). In 2016, a new arrangement – the EU-US Privacy Shield – was negotiated establishing clear safeguards and transparency obligations on US companies that import personal data from the EU.[36]

A new European regulation on data protection and security was introduced in April 2016 to strengthen the rights of citizens and give them greater control over their personal data. However, this applies to personal data and primarily protects consumers; data generated by livestock or fields do not fall within the scope of the regulation. Currently, the owner of the data is still, in most cases, the party that collects the data (manufacturers of tractors, milking robots, etc.) (PwC, 2016).

Clearly, data traffic is increasing. As the number of connected smartphones increases, data traffic, collection and generation will also increase. While the traffic collection and generation are deemed valuable, there are still numerous questions about managing the data. For example, in Nebraska (Canada), many survey respondents were comfortable sharing their data with trusted partners, such as university researchers or educators (45 percent), relatives (39 percent) and local cooperatives (39 percent). But more respondents trusted their data with "no one" (23 percent) than with equipment dealers (18 percent), equipment manufacturers (17 percent) or neighbours (13 percent).[37]

2.3.3 EXISTING DIGITAL AGRICULTURE STRATEGIES

The need for national e-agriculture strategies has been acknowledged by many stakeholders for some time; however, many countries have not yet adopted a national strategy for use of ICTs in the agricultural sector. In most countries there are many elements to e-agriculture, but all are part of the existing ICT strategy or embedded as small projects within e-government strategies (mostly OECD countries). Fully developed national strategies on digital agriculture are rare, but the existence of a comprehensive national strategy can prevent e-agriculture projects from being implemented in isolation and develop efficiency gains from intra-sector and cross-sector synergies (FAO, 2018). This is the case in some countries where FAO piloted and guided the implementation of e-agriculture strategies, such as Bhutan and Sri Lanka.

The Bhutanese e-agriculture strategy (E-RNR Masterplan) was formulated based on the Renewal Natural Resources (RNR) 5-year plan (20132018), implementation of which was led by the Ministry of Agriculture and Forests (MoAF). This masterplan aimed at harnessing the ICT potential of Bhutan to achieve its RNR goals and further strengthen the role of ICTs in accelerating the growth of the RNR sector in a sustainable and equitable manner. The vision and desired outcomes were formulated based on the Economic Development Policy (EDP 2010),[38] Telecommunications and Broadband Policy 2014[39] and e-Government masterplan adopted in 2013.

In Sri Lanka, the strategy is guided by the Agriculture Policy Framework and National Agriculture Policy framework and National Food Production Programme (2016–2018) documents published by the Ministry of Agriculture (MoA) of Sri Lanka.[40] The strategy addressed 97 challenges raised from the stakeholders' meetings, divided into eight areas, from policy and regulatory framework to data availability, knowledge, awareness and services. The core outcomes were planned and synchronized with the 3-year Medium-term National food Production Programme (NFPP 2016–2018).[41] In addition, 14 key strategic development areas were identified and connected with the ICT as part of the e-agriculture strategy. All e-agriculture services were highly aligned with the e-governmental services.

Developed countries are advancing, and are already incorporating the agriculture and food sectors in their existing or drafted digital agriculture strategies. In Hungary, the Agrarian Informatics Working Group of IVSZ prepared the draft of the Digital Agriculture Strategy.[42] This has six development programmes in two areas and identifies a horizontal programme: the development of digital competence (basic knowledge for use of digital tools and applications; education development programme; consultancy-development) to the development of a digital state (regulations and professional server systems provide state-based digital services). Also, Bulgaria drafted its own strategy that is under current open revision by public and private stakeholder engagement, and many other countries have specified digital agriculture within their national ICT or digital strategies or are in the process of implementation (Table 2-1).

Also, there are countries that do not have a specific digital agriculture strategy but most of their existing digital strategies or e-government are correlated and have some individual component or particular project in the digital agriculture field. However, this is a new field and it is likely that many governments will fail in initial attempts to transform societies into digital natives. Good examples are seen in the OECD countries, which often lack clear priorities and struggle with coordination. Only five countries have a high-level official or a special body dedicated to digital affairs that can spearhead strategy development or coordination. Too many countries are still appointing ministries or bodies which are not fully dedicated to digital affairs and which often lack the necessary competence and clout to lead on digital issues. To tackle these challenges, breaking down policy silos and adopting a whole-of-government approach to digital transformation is essential – it is time to "walk the talk" of national digital strategies. Approaches may differ across countries but there must be a coordination mechanism that

Table 2-1 Countries with digital strategies affecting the agrifood sector

Country	Strategy	Phase	Impact on agrifood
Mexico	National Digital Strategy	Implementation	Partly (education and tax)
Columbia	Online Government Strategy	Implementation	Partly (data, ICT services)
Brazil	Digital Governance Strategy	Implementation 2016–2019	Partly
Bulgaria	Strategy for Digitization of Agriculture	Drafted	High
Hungary[42]	Digital Agriculture Strategy	Drafted	High
Australia[43] (Victoria)	Digital Agriculture Strategy	Implementation	High
Greece	Digital transformation of Greek agriculture	Implementation	High
United Kingdom[44]	Agricultural technologies (agritech) strategy	Implementation	High
Ireland[45]	National Digital Strategy	Under Elaboration	Moderate
Spain	Agenda for the Digitization of the agrifood and forestry sectors and rural areas	Planned implementation 2019	High

Source: OECD, 2018; Authors, 2019.

ensures that policies in one sector are not negating or undermining those in another.[46]

2.3.4 CONCLUSION

Governments can unlock assets first by thinking of digital networks not as expenditures but as enablers, and, second, by recognizing the importance of rural communities in developing and testing new solutions, driving innovation and economic development, and attracting foreign investment. Compared with just a decade ago, governments have made significant progress in expanding ICT access. Some developed countries are reaching near universal access through fixed and mobile connections. Developing countries, meanwhile, have some way to go to catch up on access rates, but are gaining ground by expanding mobile services. Currently, there are trends in deploying e-services, especially in health, education, the environment and decent employment, while the reach to the most vulnerable is expanding.

However, many people in LDCs and developing countries are unable to benefit from ICTs because of lack of incentives, low incomes and affordability, limited user capabilities and lack of infrastructure (McKinsey & Co., 2014). These disadvantages are likely to affect further development of e-government in these countries as the pace of technological innovation intensifies, with knock-on effects on the agriculture sector. Few countries currently provide e-agriculture services. However, those countries that do put emphasis on ICT for the agriculture sector have better "doing business" environments and better policy and regulation for agribusiness. In most cases, policy and regulations are not related to level of education, literacy or agricultural contribution to GDP in a given country.

The type of licensing framework and efficiency of spectrum allocation are important in encouraging the private sector to invest and rollout mobile networks in remote areas. The experience of EU countries suggests that greater liberalization of the telecommunications sector, including introduction of general authorization regimes, supports ubiquitous connectivity. Efficient spectrum management is another regulatory stimulus than can provide benefits to MNOs through lower deployment costs and innovation opportunities, and to the end user in terms of greater access to ICT services.

Developed countries are leading on fully elaborating and implementing national level strategies on digital agriculture. In addition, some developed countries have high engagement with the process of digitalizing the agrifood sector through existing national digital strategies that aim to transform the entire industry and society with one of the components on which they focus being the agriculture and food sector. In developing countries, most e-agriculture services are embedded within the e-government or wider ICT strategies, with the main objective being to provide some basic e-agriculture services, mostly early alert notifications and generic information.

3 ENABLERS FOR DIGITAL AGRICULTURE TRANSFORMATION

Digital technologies have had a transformational effect on our daily lives and are an accepted part of most areas, including communication, work, self-care and transport. High-speed Internet connections and Web-enabled smartphones have made it easier than ever to find and access information on the Internet. As more people turn to the Internet for news and information, traditional media sources such as newspapers and print magazines are in decline. Those who are connected can leapfrog barriers to accessing required information, and mobile apps, social media, VoIP and platforms can make life easier, particularly for those in rural and remote areas. However, despite there being tens of thousands of existing applications in the area of agriculture, many smallholder farmers in developing countries are divorced from technology and vital agricultural support services needed to carry out farming activities.

As discussed in Section 2, basic conditions are needed to unlock the process of digital agriculture transformation in attempts to ensure all are connected. But, in addition to these basic conditions, further enablers are required to establish the impetus of the digital agriculture ecosystem. We must create suitable environments for digital-native farmers and locally based innovative agripreneurs. Indeed, we are seeing more funding rounds, more funds, more collaboration, and worldwide digital agriculture start-ups making a name for themselves on the global stage, attracting international investor, accelerator and media attention. In addition to some solid exits and acquisitions, we have also seen the emergence of these digital agriculture start-ups acquiring start-ups all signs of a sustainable digital ecosystem in the process of becoming more mature and consolidated.

To speed up this process and interaction between farmers and agripreneurs, we need to work with youth, as they have the considerable advantage of extensive digital literacy and innovative solutions. With this knowledge, the future belongs to them. They have in their hands the skills to become the responsible leaders that our schools and societies expect them to be. The excellence of tomorrow's agricultural and IT engineers rests on understanding the uses of digital tools and the issues surrounding them. The digital revolution is under way and it is accelerating. Integrating the digital dimension at the heart of educational programmes and sprint programmes will help to promote innovation and creation in students and youth agripreneurs, serving the world of tomorrow's agriculture.

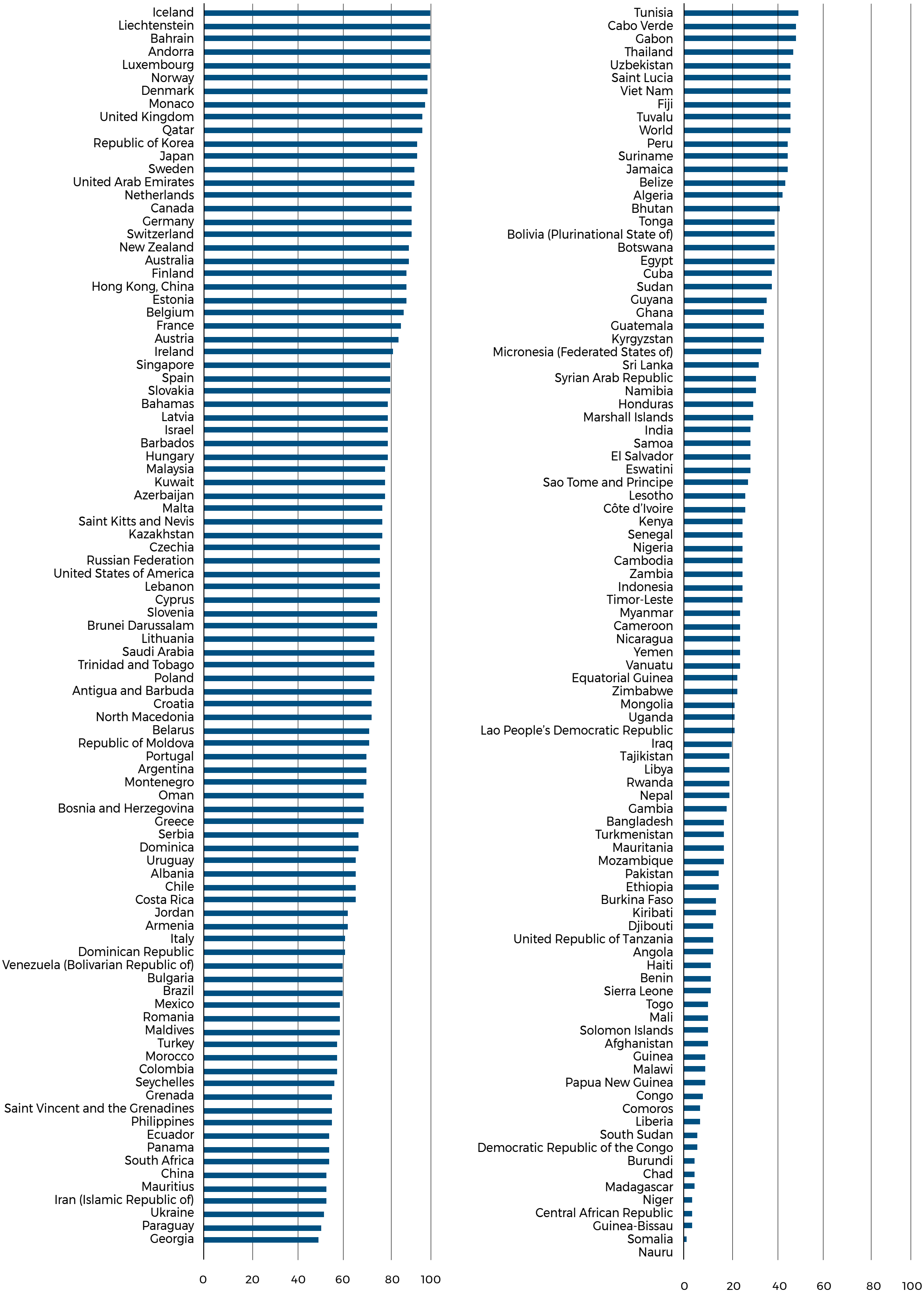
This Section provides an overview of three key enablers, and is divided into sub-sections aiming to describe current global trends and challenges in the process of digital agriculture transformation. Use of mobile and social networks for agriculture and food purposes among farmers and extension officers is a starting point (Section 3.1) for further discussion on how to bridge the gap between technologies and end users, in this case all stakeholders in the value chain, and the digital skills trends and demands for the future of the agrifood sector (Section 3.2). Section 3.3 describes global trends and investment in digital agriculture and key challenges to the future of digital agriculture start-ups and their role in the agrifood sector. We highlight the importance of innovation in the field of digital agriculture and the need for cooperation among all stakeholders in the value chain as a precondition for a sustainable operational model to drive global digital agriculture.

3.1 Use of digital technologies among rural population and farmers

There can be reduced access to Internet connectivity in developing countries, and there are low literacy rates in people living in these regions who lack basic digital skills. According to GSMA (2018), women and youth are disproportionately affected by these challenges. In recent

Figure 3-1 Percentage of individuals using the Internet, 2016.

Source: ITU, 2017.



years, there has been immense development in mobile broadband, enabling enhancement of mobile financing, mobile agriculture, health and various other services. A study conducted by ITU (2016) shows that almost every second person in the world, or 47 percent of world's population is using the Internet. However, this number is significantly lower in LDCs, where it accounts for only one out of seven people. Developed economies are home to 2.5 billion Internet users, compared with 2 billion users in the developing economies (ITU, 2016).

As of 2017, China had the Internet users worldwide. The country had 550 million urban Internet users, which represents 73.3 percent of the nation. Compared with 2016, there was an increase of 19.88 million users in 2017 (CNNIC, 2017). However, connecting rural areas and villages remains China's main priority, and according to ADB (2018) by the end of 2016 almost 90 percent of administrative villages in China had received broadband access. Significant progress has also been registered in urban regions of India. However, compared with other countries, there are still low numbers of Internet users in rural regions of India (Kantar-IMRB, 2017). In EU-28 the statistic is opposite to that of India. In 2017, the percentage of EU-28 rural users of Internet was 87.2 percent, whereas in the United States there were 67 percent rural Internet users and 70 percent urban Internet users (US Census Bureau, 2017).

3.1.1 INTERNET USE AND GENDER GAP

Access to the Internet remains the most critical component for unlocking the possibilities of new technologies, but universal Internet access is a challenge. The global Internet gap is also a gender issue. In 2016, the global Internet user gender gap grew to 12 percent, an increase of 1 percent compared with 2013. This gap is even wider in LDCs; in 2016 it was 31 percent. A report by ITU (2016) showed that among regions Africa had the largest regional gender gap of 23 percent, while this gap was smallest in the Americas (2 percent). The report also gives striking figures that almost 25 percent fewer women than men from developing economies have Internet connectivity. In some parts of sub-Saharan Africa this figure rises to almost 50 percent. Also, in some OECD countries the gender gap in Internet use is higher than the world average. An OECD report (2019) shows that in Turkey the gender gap is highest at 18 percent, compared with 10 percent in Chile and 8 percent in Italy. In Latin America, the gender gap in Internet users varies between countries: it is lowest in Uruguay at 0.7 percent, whereas in Guatemala it is 10 percent. Interestingly, there are also countries in this region that register gender gap differences in favour of women. For example, the gender gap in Colombia is 0.1 percent, while in Jamaica this difference reaches 5.5 percent (ECLAC, 2017).

According to ITU (2016), in most countries, the proportion of male Internet users is higher than the proportion of female Internet users. However, Figure 3-3 shows that in China the numbers of male and female Internet users are similar, with a slightly higher figure for female users (52.4 percent). In contrast, in India there are only 29 percent female Internet users, mainly because females living in rural regions often encounter restrictions on their use of ICTs because of their gender (Kantar-IMRB, 2017). In a village in rural Rajasthan, the village 'rules' state that rural women are not allowed to use mobile phones or social media. Also, in Bangladesh and Pakistan, men are twice as likely as women to own a mobile phone. In the United States, similar to China, the distribution among men and women is almost equal, but contrary to China, in the United States there are more male users, accounting for almost 83 percent of Internet users out of all male population.

Figure 3-2 Internet user gender gap (percent), 2013 and 2017 by region and economic development
Source: ITU, 2017.

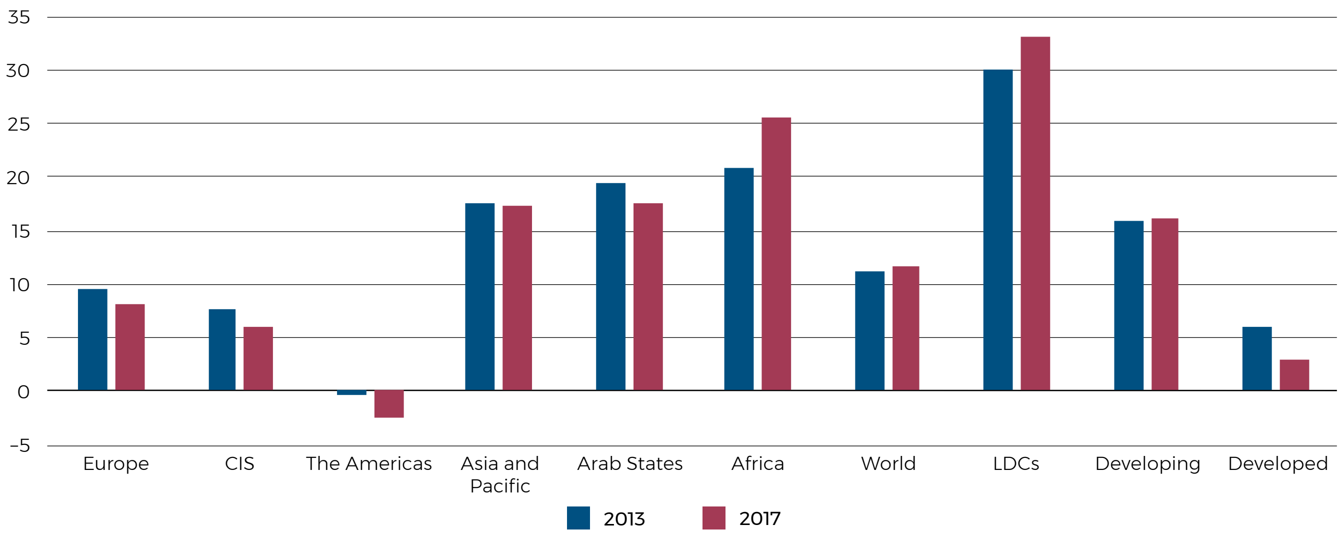
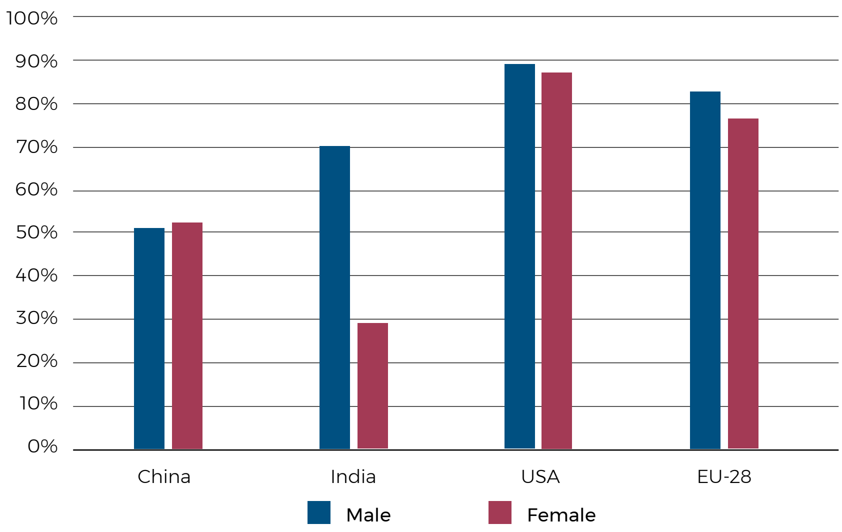


Figure 3-3 Share of male and female Internet users in some countries, 2017.
Source: CNNIN, Kantar-IMRB, Pew Research Center and Eurostat.



The Internet makes daily life easier; no matter what the question, the answer can be found on the Internet. The young population is the main driver for increased Internet usage. However, access to the Internet remains limited in regions affected by deprivation (Chair and De Lannoy, 2018). Service of access to the Internet remains expensive, weak and unreliable in these regions, and tech-devices themselves are expensive. Moreover, people in deprived regions can lack digital literacy and skills, hence Internet usage among young people in Africa remains at low levels.

3.1.2 INTERNET USE AND YOUTH

In 2017, ITU estimated that 48 percent of the world population was using the Internet. Of these, and estimated 71 percent of the users were aged 25 or younger. In developed countries 94 percent of young people aged 15–24 use the Internet, compared with 67 percent and 30 percent in developing countries and LDCs, respectively. In Africa, 37.3 percent of the young population is using the Internet. This figure is higher than the total population on the continent having access to Internet (21.8 percent) (ITU, 2017).

Deen-Swarray and Chair (2016) found that between 2008 and 2012 there was increased Internet and mobile uptake by youth in Kenya, South Africa, Mozambique, Namibia, Ghana, Botswana, Nigeria, Tanzania, Uganda, Cameroon, Ethiopia and Rwanda. Mobile phones were identified as the first point of access to the Internet, with exceptions in Rwanda, Ghana and Cameroon. Top access points for the Internet for youth 15–24 were mobile phones (73 percent), Internet cafes (54 percent) and educational institutions (41 percent) (ITU and UN-Habitat, 2012).

Figure 3-4 Percentage of youth (15-24) Internet users and youth in total population, 2017.
Source: ITU and WBG, 2017.

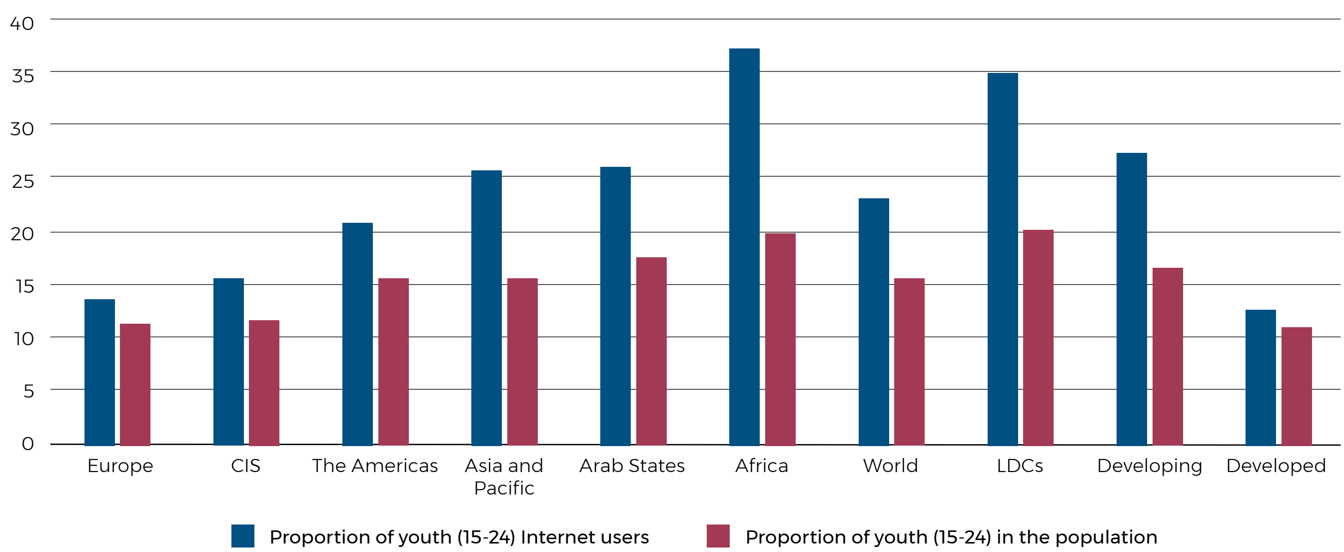
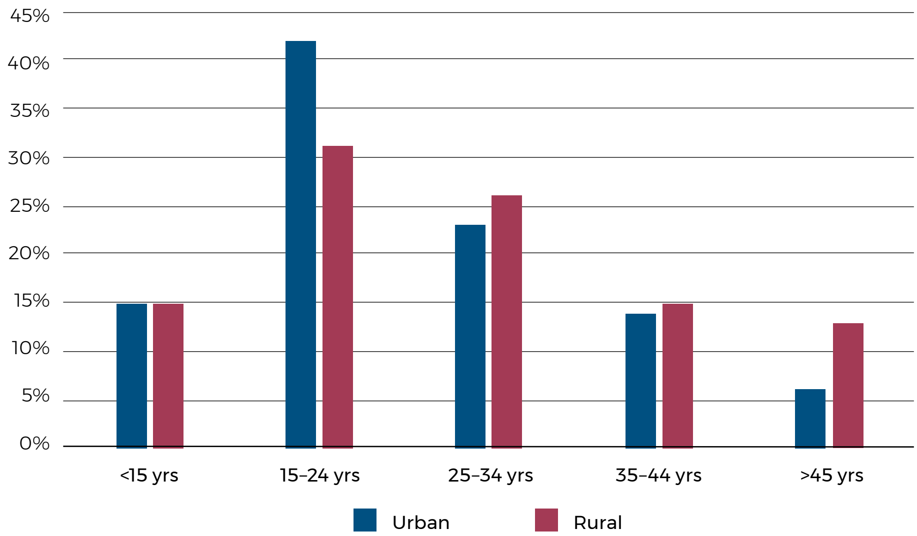


Figure 3-5 Internet users' demographics in India (as percentage from total group population), 2017.
Source: Kantar-IMRB, 2017.



In Latin America, youth aged 15–24 form the group with the highest number of Internet users, both male and female. In this region, the biggest gap is in people aged 25–74 years. In Peru, there are 6 percent more male Internet users, while in Panama there are 4.1 percent more male Internet users than female. On average, youth aged under 15 and 15–24 years, have more female users than male, and the figures are 0.4 percent and 0.6 percent, respectively (ECLAC, 2017).

In India, the figures are different. Mobile Internet is mainly used by youth, aged under 25 years, with 46 percent of those aged under 25 from urban regions using mobile Internet compared with 57 percent of similar users from rural regions. In the age range 25–44, usage is almost equal in rural and urban areas; however, in those aged 45+ usage in the urban population is almost twice that in the rural population.

Eurostat reports show that in 2013, 70 percent of women aged 16–74 had access to the Internet in their household, which is 4 percent less than for men in the same age group. At their workplace the figures for Internet access were 29 percent and 35 percent, respectively, for women and men. Furthermore, 32 percent of women had Internet access on their mobile phone, while this figure was 39 percent for men. Also, 21 percent of women with a tablet or laptop had access to the Internet (27 percent of men) (European Parliament, 2018). A gender gap is visible within EU-28 for various purposes of Internet usage (Figure 3-6).

Figure 3-6 Gender gap in use of the Internet in EU-28, 2017.
Source: Eurostat, 2018a.

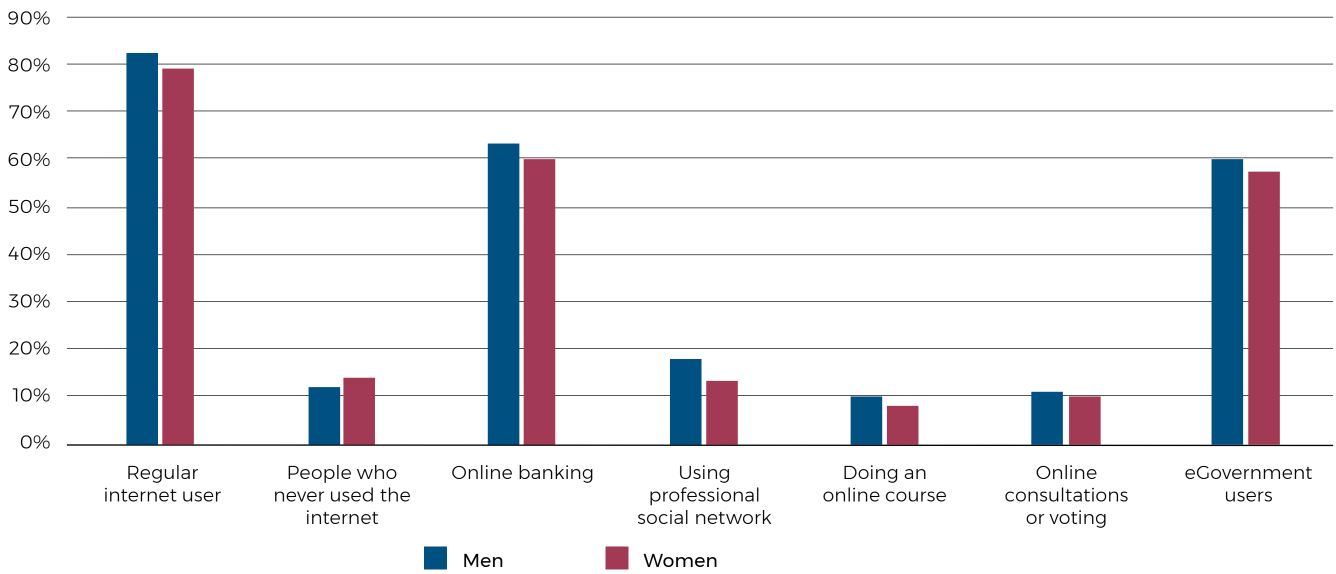


Table 3-1 Causes for limitation of Internet access in some countries

	Nigeria		Rwanda		United Republic of Tanzania	
Age, years	15–19	20–24	15–19	20–24	15–19	20–24
Lack of time, %	10.7	9.1	31.4	35.0	21.4	22.9
Expensive, %	35.1	47.5	70.6	50.2	41.3	42.3
Speed of Internet, %	9.1	14.5	17.0	6.3	26.8	16.7
Surveillance/privacy concerns, %	4.5	3.4	3.6	5.4		0.9
Restricted use, %	2.7	1.3	2.0		7.8	
Find it difficult to use, %	1.2	1.3		24.0	3.1	5.4
Lack of local language content, %			2.0	33.6	11.7	1.5
No interesting content, %			5.9	4.1		3.7

Source: Chair and De Lannoy, 2018.

Although, in the developed world, access to the Internet is easily accessible and affordable, it remains a constraint and privilege in the developing world, especially among the young and unemployed population. In a survey conducted by Chair and De Lannoy (2018) in several African countries (Table 3-1), the main reason given for limited access to the Internet among the youth population is the high cost. A high rate of unemployment is a common characteristic for youth in these countries. In addition, the lack of local language content was reported to be a significant barrier among those aged 2024 in Rwanda and those aged 15–19 in Tanzania.

The Internet is presented as a panacea for the challenges that young people face, but this is not necessarily the case. Despite being the main drivers of Internet uptake, use of the Internet among youth is still not optimal, especially in regions and countries affected by deprivation (Chair and De Lannoy, 2018).

Chile represents a paradox and it is a relevant case for studying Internet use and ICT adoption in rural communities. According to ITU (2013), Chile is the leader in Latin America in terms of Internet connectivity and also the leader in ICT public policy (Kleine, 2013). In Chile, 61.1 percent of households have Internet connections; however, the urban–rural gap has widened. (ITU, 2016). According to Rivera, Lima and Castillo (2014), the last national survey on Internet connectivity showed that the main constraints for Internet connection in rural areas were lack of relevance (38 percent), utility (19 percent), lack of coverage (15 percent) and cost (14 percent). These figures suggest coverage and cost of Internet are not as important as relevance and motivation.

3.1.3 MOBILE USE, SOCIAL MEDIA AND NETWORKS

In the sub-Saharan region, almost 80 percent of the owners of mobile phones use their devices mostly for sending text messages. In South Africa, 95 percent of mobile phone owners use their devices for sending messages and in Tanzania this figure is 92 percent, compared with at least half of all mobile phone owners in other African countries (Pew Research Center, 2015). In 2017, globally there were 49.7 percent of users with mobile Internet access, and most of these users were located in Asia and Africa. The highest rate of mobile Internet traffic was registered in Kenya, followed by Nigeria, India, Singapore, Ghana and Indonesia.[47] Moreover, globally the average daily usage of Internet through a mobile phone is 3 hours and 14 minutes. Thailand is the top ranked at more than 5 hours per day (Hootsuite and We are social, 2019).

Mobile phone users use their devices for different activities, mostly differentiated by age, gender and personal preferences. The most common activities are phone calls, sending text messages and e-mails, making videos and social networking.

According to Ouma *et al.* (2017), 56 percent of the adult population in Uganda have used mobile money services for cash withdrawals, followed by receiving (54 percent) and sending money (46 percent). In Malawi, 42 percent of the adult population use mobile purchase airtime, while around 30 percent use mobile phone services for cash withdrawals, followed by receiving money (23 percent), sending money (18 percent) and cash deposits (17 percent). The Pew Research Center (2015) showed in the young population in Africa, it is mostly those with higher education and good English-language skills who engage in these mobile activities. For example, in Ghana, 65 percent of mobile owners are aged 18–34 and are using their mobile devices for sending text messages. In contrast, only 34 percent of mobile users aged 35 and over are engaging in above activities. In addition, 62 percent of young mobile phone owners in Ghana use their devices for taking pictures or videos, but only 33 percent of the older generations do this (Pew Research Center, 2015).

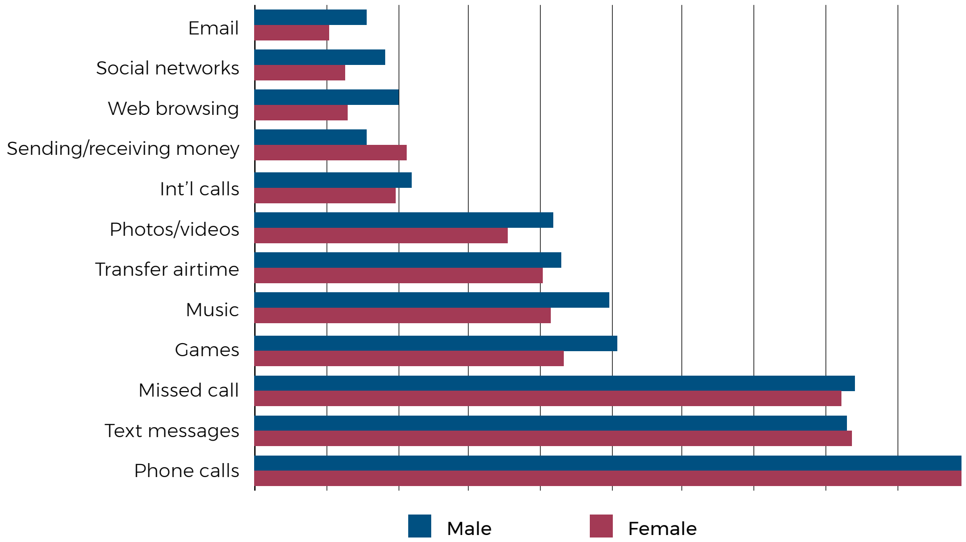
In EU-28, in 2016 over half (52 percent) the population aged 16–74 used the Internet for social networking. Most of these people were located in capital city regions and across Nordic countries and western EU Member States. The only exception was France, in which most regions had relatively low shares participating in social networking (Eurostat, 2017b).

Pattern of mobile usage, apart from varying based on age and gender, also differ fiercely across urban and rural regions. In urban Indian regions for example, services such as social networking, e-mails and online shopping are prevalent, whereas in rural parts of the country the Internet is mostly used for entertainment in the form of video and audio content (Kantar-IMRB, 2017).

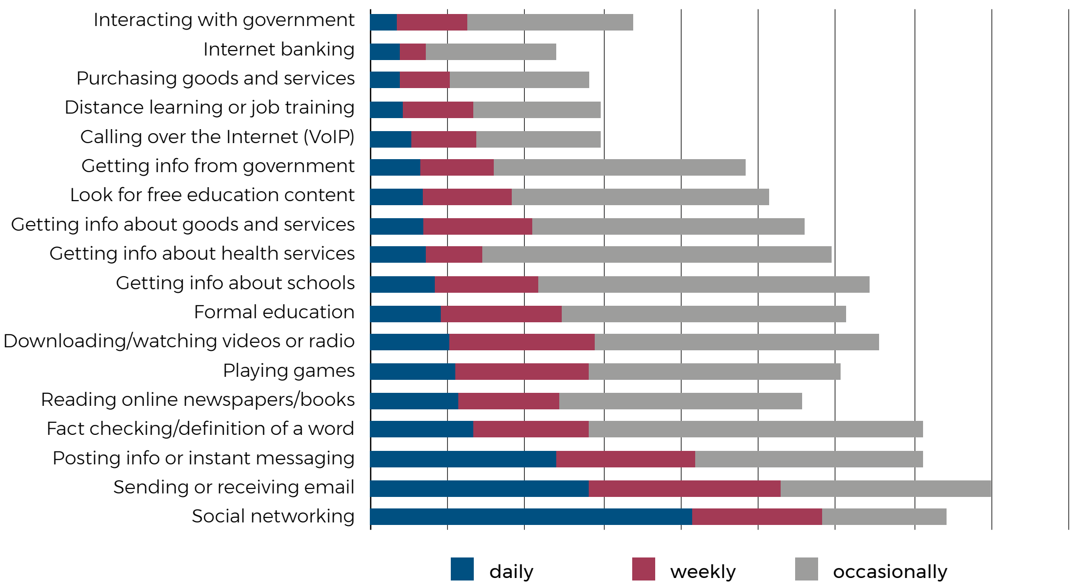
Figure 3-7 Percentage of individuals who use mobile phones or Internet by purpose of use in Africa, 2011–2012

Source: Research ICT Africa survey, 2018.

a) Mobile usage

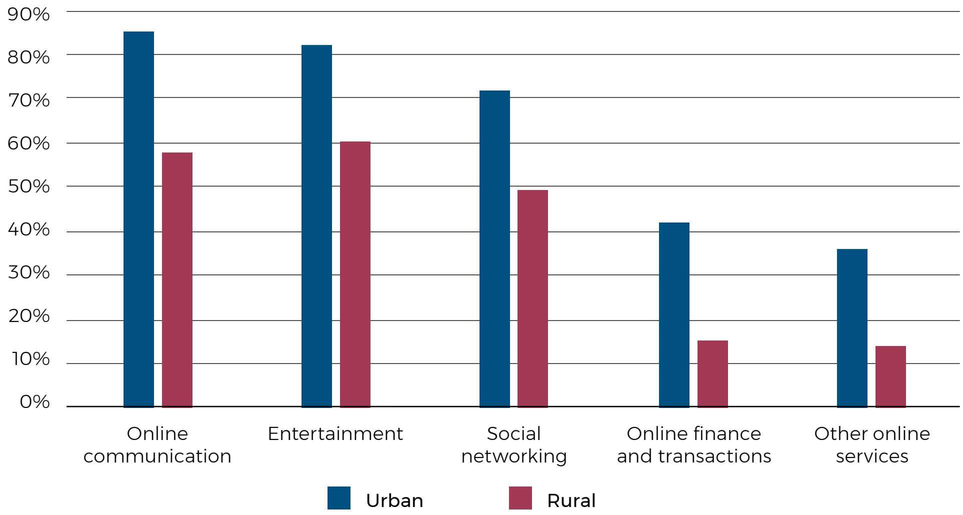


b) Mobile internet usage



Note: Data are averages from 12 African countries.

Figure 3-8 Purpose of mobile Internet access in India by degree of urbanization, 2017.
Source: Kantar-IMRB, 2017.



As mobile devices are the major source of Internet access globally, this has implications for social media usage. The focus should be how to best exploit and combine mobile and social media in terms of changes and development of daily life of the population worldwide (GFRAS, 2016). The number of people worldwide using social media is rapidly growing, and the numbers of users of the top platforms in each country have increased by almost 1 million new users every day during the past 12 months. This means that every second there are 11 new users registered. In 2018, worldwide there were more than 3.4 billion people using social media each month, and 9 out of 10 users accessed their chosen platforms via mobile devices (Hootsuite and We are social, 2019; We are social and Hootsuite, 2018).

Eilu (2018) reported that social media is the main reason for use of mobile Internet in sub-Saharan Africa. However, despite the rapid global increase of the Internet and mobile phones and device use, there is a lack of research on use of mobile Internet and social media in rural communities in sub-Saharan Africa. Eilu highlights the need for technology in rural communities in sub-Saharan Africa.

According to Hootsuite (Hootsuite and We are social, 2019), Central and Southeast Asia have recorded the fastest gains in social media penetration, with more than 90 percent and 33 percent, respectively. Taiwan, Malaysia and the Philippines have reached 99 percent of social media penetration. The fastest individual country growth rate was registered in Saudi Arabia at 32 percent, with 87 percent penetration rate. This is followed by India, with 31 percent annual growth in social media users.

On the other hand, in Nigeria usage of social media remains low, with 19 percent of the population being active users of social media. In Ghana, 29 percent are active users, while the registered highest penetration

Figure 3-9 Global mobile social media penetration, 2017.

Source: GSMA, 2018.

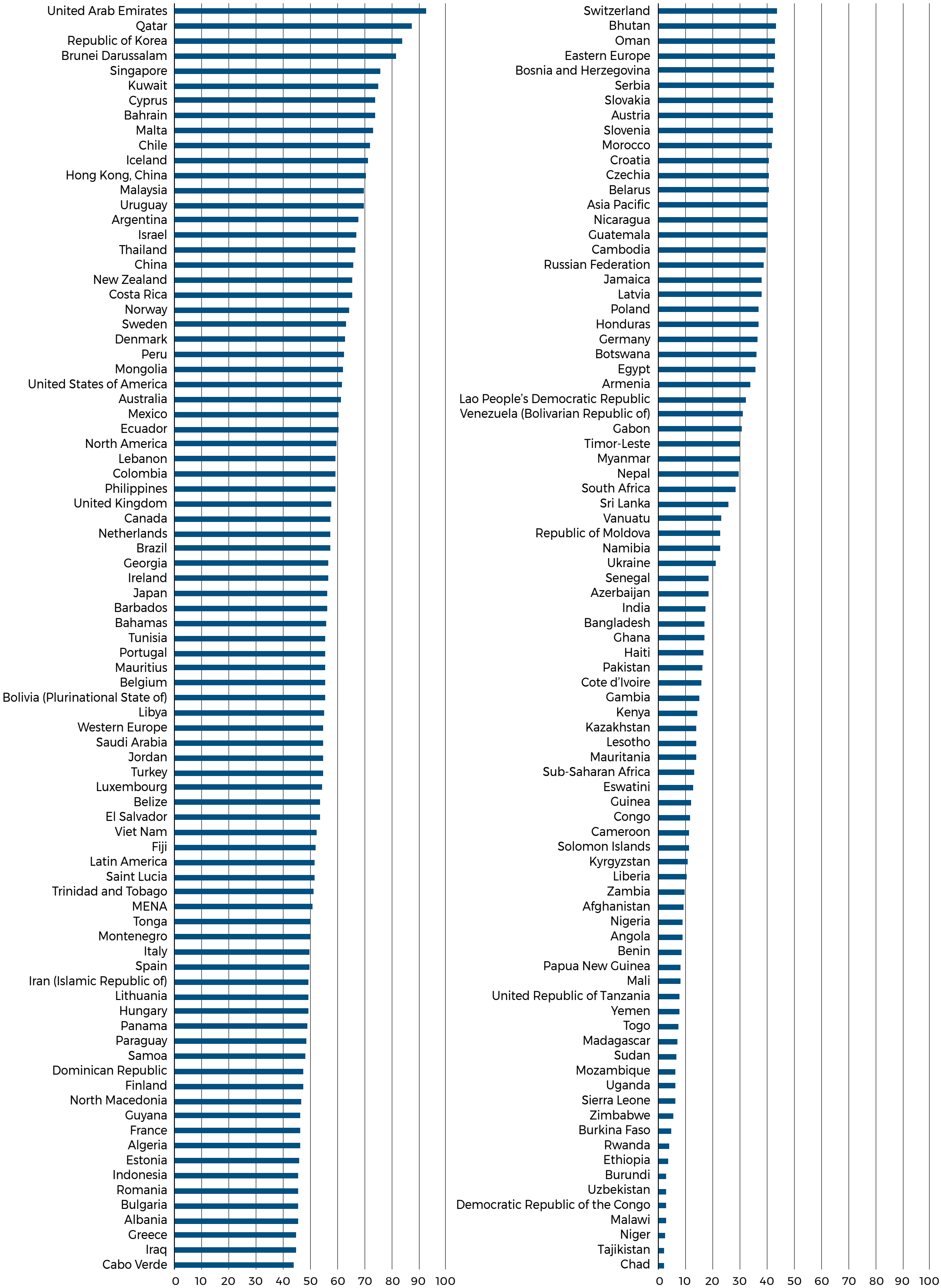
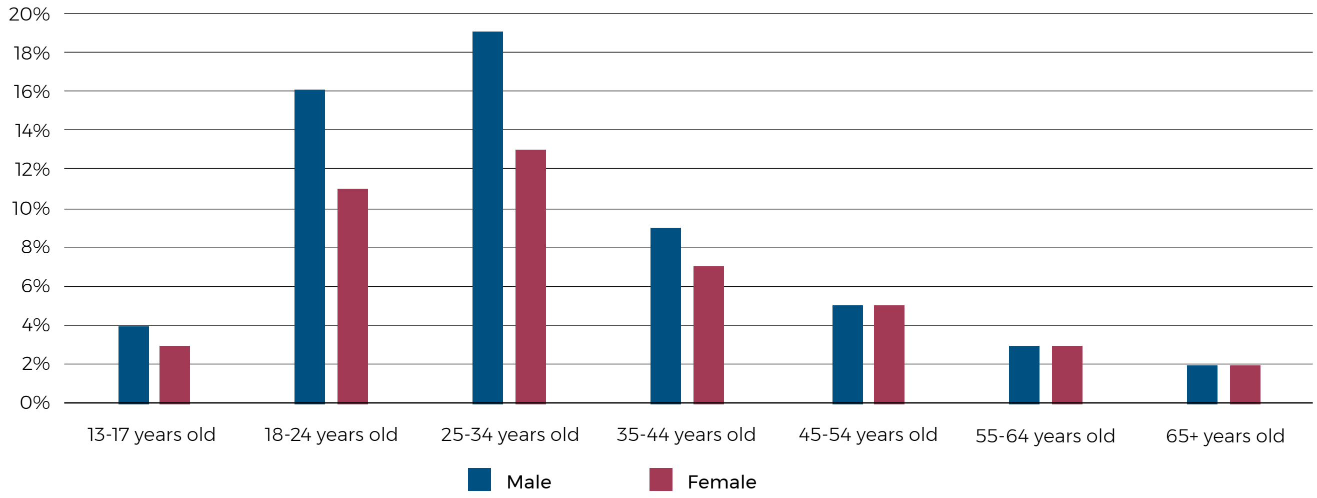


Figure 3-10 Social media users by gender and age, 2019.
Source: Hootsuite and We are social, 2019.



level in Nepal is just 23 percent. One potential reason for low social media usage is the exceptional difference in access for women and men. In India for example, only 24 percent of Facebook users are women. In Bangladesh that figure is slightly lower, at just 23 percent, and in Pakistan, it is even lower, at barely 22 percent (We are social, 2016). The gender gap is even more clear among the younger population.

According to the ECLAC Database (2015), one reason for the digital divide in terms of social media use is level of education. In Latin America and the Caribbean, those who have completed secondary or tertiary education are more frequent users of social media then those who have completed only primary education or have had no education. In most countries in Latin America, people with no formal education are not users of social networks and media. The only exceptions from this are seen in Ecuador and Costa Rica, with 45 percent and 44.9 percent social network users, respectively, who have no education.

The global social landscape is dominated by Facebook's core platform, with the total number of users increasing by 15 percent on a yearly basis, reaching almost 2.27 billion at the beginning of 2019. WhatsApp and Facebook Messenger both grew twice as fast as the core Facebook platform, with the number of people

Figure 3-11 Share of population who use social networks by educational level in Latin America and Caribbean (percentage of total population), 2015.
Source: CEPLSTAT, 2019.

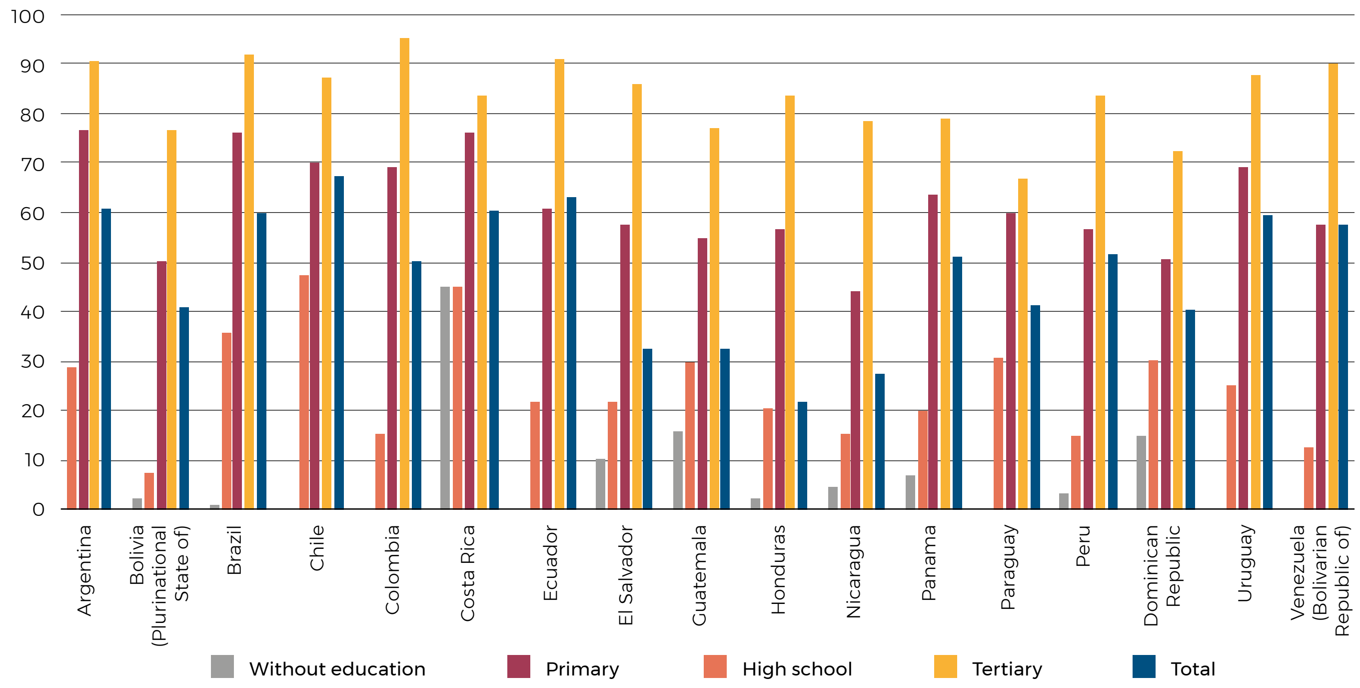
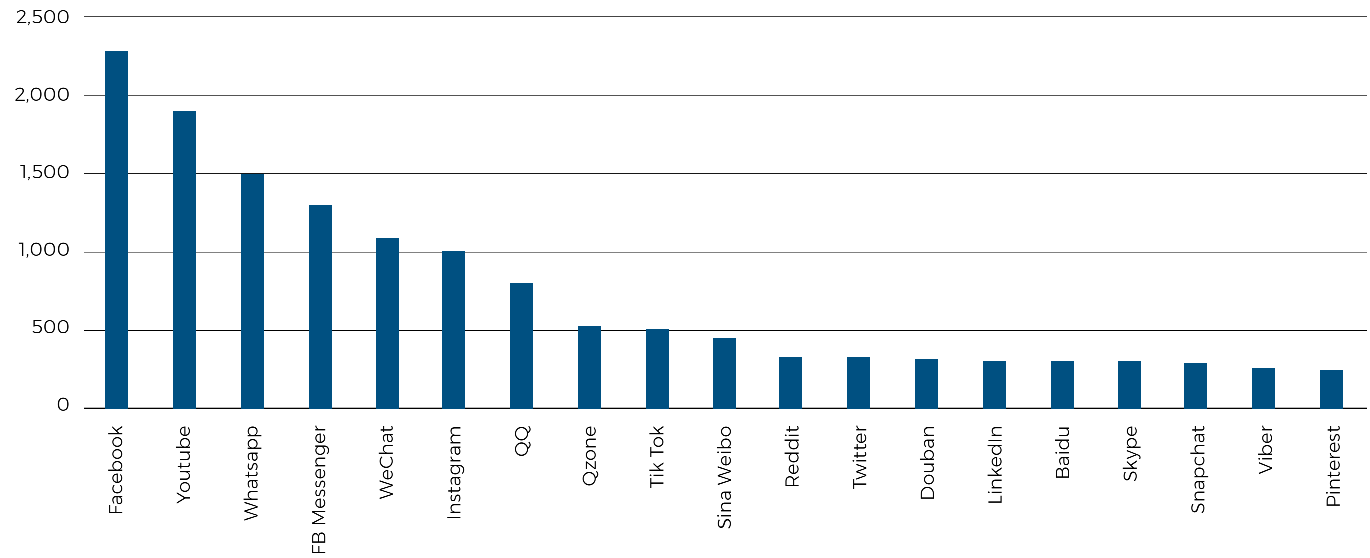


Figure 3-12 Social platforms and VoIP active user account (in millions), 2019.
Source: Hootsuite and We are social, 2019.



using these Facebook messenger applications rising by 30 percent from year to year.

WhatsApp has a stronger geographic position compared with Facebook Messenger, being the top messenger application in 128 countries worldwide, but both applications have almost the same number of users. Interestingly, there are only 25 countries around the world in which a Facebook-owned application is not the most used messenger platform.

Pew Research Center (2018) reported that YouTube and Facebook also dominate in the United States. Most of the younger population in the United States, especially those aged 18–24 are using different social media platforms and are notable for using them frequently. Most of these young people (78 percent) use Snapchat and a sizeable majority of these users (71 percent) visit the platform more than once a day. In rural areas in the United States, there are fewer social media users than in urban areas. Furthermore, there is a significant difference in usage of LinkedIn and Twitter platforms among users in urban and rural areas of the United States.

Research into the purpose of use of mobile apps is lacking. The latest data from App Annie (2019) show that people now spend seven longer using mobile apps compared with mobile Web browsers. In Indonesia, for example, mobile users spent over 4 hours a day on Apps. In 2018, in developed markets such as the United States and Canada, the average user spent nearly 3 hours a day on mobile Apps.

Figure 3-13 Percentage of US population who use each social media platform by degree of urbanization, 2018.
Source: Pew Research Center, 2018.

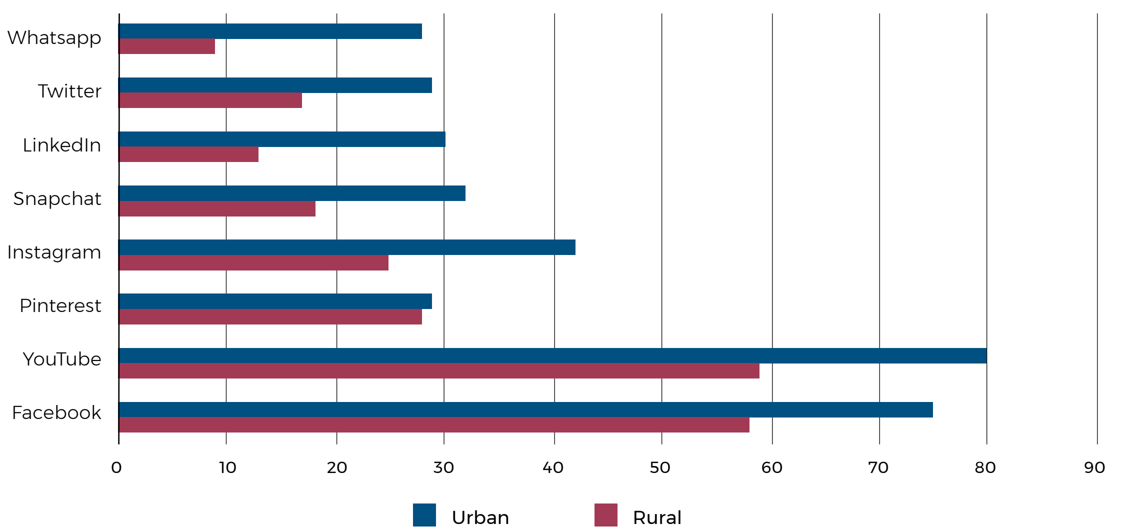
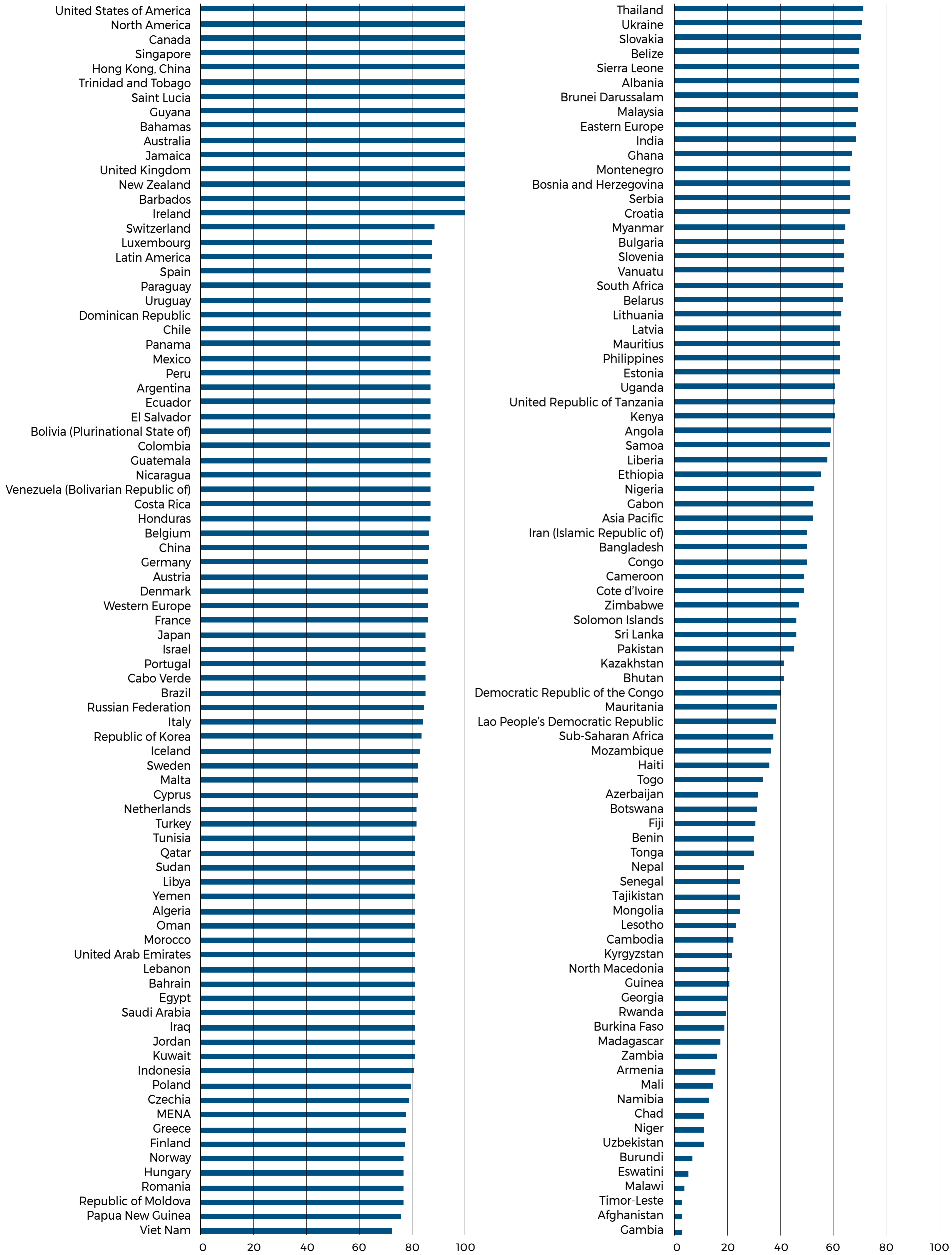


Figure 3-14 Number of mobile apps accessible in local languages, 2017.
Source: GSMA, 2018.



In general, populations of rural communities show low usage of the Internet and social media, with the emphasis on networks and platforms such as Facebook, WeChat, Twitter, etc. This is especially visible among indigenous populations and local tribe language-predominant areas. Among other limitations, is information availability in local languages. As the level of education and literacy are lower in rural areas compared with urban area, appropriate social media content is desirable.

Figure 3-14 shows that developed countries and those countries in which the official language is one of the world's most spoken languages (English, French, Spanish, etc.) have more available apps in the local language then countries in regions such as Asia and the Pacific region and sub-Saharan Africa, in which most nations speak either local tribe language or unique national language.

3.1.4 MOBILE APPS, SOCIAL MEDIA AND NETWORKS AMONG AGRICULTURE STAKEHOLDERS

3.1.4.1 Mobile apps for agriculture

There has been extensive growth of mobile apps to support business, for example in tourism, entertainment, health, shopping, education and farming. Mobile agricultural apps show significant potential for modernization of the agricultural sector, in both developed and developing countries. For example, mobile apps can play a part in increasing the income of small-scale producers, reducing the supply and distribution transaction costs, improving traceability and quality criteria for consumers, but also for providing opportunities for financial institutions (Costopoulou, Ntaliani and Karetsos, 2016).

Mobile apps stores offer a wide variety of apps for food and agriculture, and it can be difficult for consumers and farmers to choose from the increasing number of available apps. Worldwide, in 2018, 115 percent more downloads were registered of the top five food-delivery apps compared with 2016. In 2018, the top two food-delivery apps by downloads were dUberEats[48] and Zomato.[49] Analysed by country, India had the strongest growth at 900 percent. App Annie (2019) states that there was also high demand for food-delivery apps in the western markets, such as Canada and the United States, up 255 percent and 175 percent, respectively.

In developing countries, there is also an impressive variety of agricultural apps, offered by either public organizations or local enterprises supported by MNOs. In India, mKisan[50] is a popular government portal that offers a variety of mobile apps for agriculture, horticulture, animal husbandry and other agricultural fields. Also, Digital Green[51] operates in India, an information provider with a focus on agricultural extension and increasing its efficacy and cost-efficiency. In Kenya, there is a popular SMS and voice mobile app, called iCow,[52] providing information as part of a subscription service. The aim is to increase productivity of farms through access to expertise, information and knowledge. This app also operates in Tanzania and Ethiopia. Similar to this, WeFarm[53] is another SMS service app, aiming to enable small-scale farmers to ask questions via SMS and receive answers from other registered users in Kenya, Uganda, Tanzania and the Ivory Coast. Esoko[54] and M-Pesa (owned by the Vodafone Group) operate in various countries, providing information to farmers on different segments in the agrivalue chain through SMS and voice. In Nigeria, in 2012, the Nigerian Central Bank and country's Ministry of Agriculture introduced a mobile wallet programme a digitized voucher distribution for subsidized fertilizer, or Smart Money. It is a saving-payment system and now also operates in Uganda and Tanzania. This solution substitutes cash payments in the entire value chain. Large agribusinesses transfer electronic crop payments through Smart Money to e-wallets of intermediary buyers, who, in turn, also use the system to pay small farmers.

Large international companies are crucial players in this market. In recent years they have been focused on developing and introducing apps. For example, Monsanto offers "Climate Field View",[55] a digital agricultural platform that provides data on weather, soil and crops at field level to help with production decisions. DuPont Crop Protection developed a new "Tank Mix App"[56] that helps farmers with calculation of products and water needed per tank or by area. Also, Bayer Crop Science in Germany offers apps for verification of 232 pests and 218 diseases in different crops, and also provides recommendations for applicable control measures. "Weed ID App"[57] in the United Kingdom is implemented by BASF, with the main aim of identifying 140 weed species. Moreover, BASF offers "Cereal Disease ID App",[58] which gives quick mobile access to information on 36 cereal diseases (information such as symptoms, life cycle, host, importance and control options).

In 2016, for users on the Android operating system there were 561 available apps related to agrifood activities. On the iOS operating system there were 589 apps. These apps can be divided into several categories: business and financial data, animal production, farm management (crops), pests and diseases, agricultural technology and innovation, agricultural machinery, spraying related activities, weather forecast, training, agricultural news and others (relevant to the agrifood sector).[59]

Table 3-2 shows the actual numbers by the end of 2016 for Android and iOS mobile apps for each category. As the Windows Phone was relatively new in 2016, it has only 42 mobile applications for the agricultural sector. Many of these are displayed on more than one of the app stores. The most popular app is related to agricultural equipment and has been downloaded over 100 000 times (Costopoulou, Ntaliani and Karetsos, 2016).

Table 3-2 Agricultural Mobile Apps, 2016.

Category	Android	iOS
Business and financial data	121	123
Animal production	65	65
Farm management (crops)	69	91
Pests and diseases	20	24
Agricultural technology and innovation	73	88
Agricultural machinery	39	35
Spraying related activities	30	31
Weather forecast	18	17
Training	41	39
Agricultural news	41	46
Other	44	30
Total	**561**	**589**

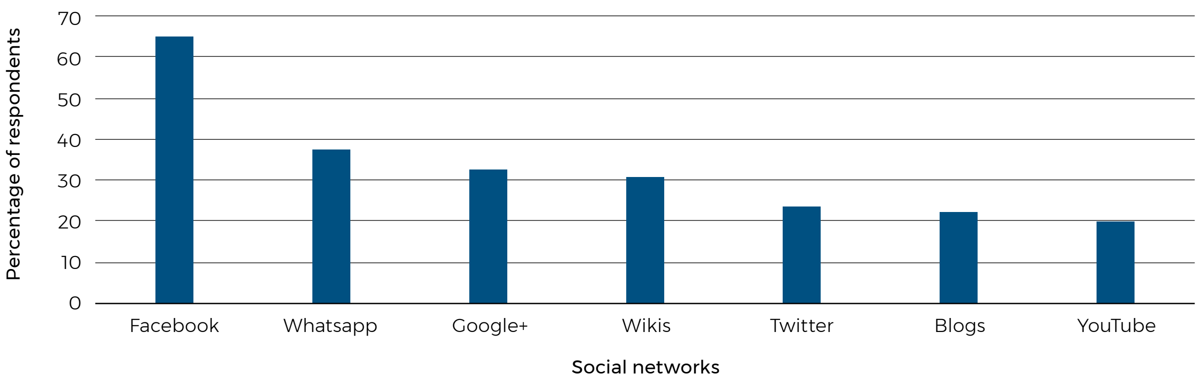
Source: Costopoulou, Ntaliani and Karetsos, 2016.

3.1.4.2 Social media and agriculture

Social media is a platform of engagement, and for agricultural producers the major reason for using such a platform is mass influence (Varner, 2012). It gives farmers a voice and an opportunity to directly connect with customers, which can help in direct marketing aiming to increase profits alongside facilitation of masspersonal communication (Carr and Hayes, 2015). To agriculture as an industry, the key values of communication provided by social media are peer-to-peer networking, farmer to processing industry to consumer engagement (Stanley, 2013). Sokoya, Onifade and Alabi (2012) opined that there is increasing use of social media among agricultural researchers, professionals and others stakeholders in the agricultural sector. Social media such as YouTube, Facebook, blogs, Wikis and podcasts provide large potential for use by extensionists, but the content and outreach must be determined based on users (Gharis *et al.*, 2014). Bhattacharjee and Saravanan, (2016) reported that a search on YouTube with the keyword "farming" gave about 300 000 hits, whereas the keyword "agriculture" gave almost three times more hits, about 889 000, while "agricultural extension" gave 10 400 hits.

In recent years, there has been trend for increased use of social media by farmers. "Farm selfies" are trending on Facebook. Bhattacharjee and Saravanan (2016) conducted a study of 62 countries, and found that Facebook was the most used social network among agriculture stakeholders (Figure 3-15). One of the largest agriculture groups on Facebook is "Digital Farmers Kenya", with 336 000 members, sharing good and promising practices for agriculture and food. Another is "Africa Farmers Club", with 127 000 members, established by young, enthusiastic farmers, with the aim of bringing African farmers closer by sharing tips, experience, successful stories and encouragement. Similar platforms exist in Southeast Europe, particularly in ex-Yugoslavian countries, and are equally successful. The Facebook group "Dobra zemlja" has 124 000 members from the region, who share issues similar to those described for the platforms above.

Figure 3-15 Social media preferences among agriculture stakeholders (in percent), 2016.
Source: Bhattacharjee and Saravanan, 2016.



Note: Includes 62 countries.

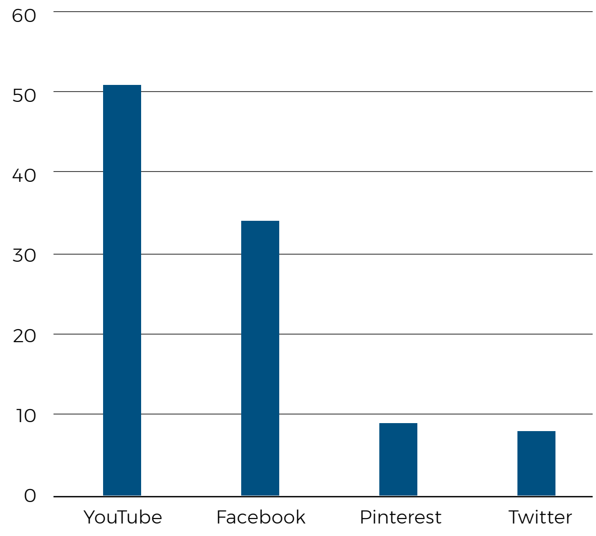
In addition to the social networks, digital tools (VoIP) such as WhatsApp are also used for interaction between agrivalue chain stakeholders. The Department of Agriculture in the Indian state of Karnataka has made it mandatory for agricultural development officials to have a smartphone so they can share information, messages and circulars through WhatsApp. Similar to Facebook, the WhatsApp group "Baliraja" allows farmers from different villages to seek and share agriculture advice as well as connect with experts in various fields and learn new practices.[60]

In 2017, MarketingtoFarmers.com[61] reported that YouTube was the leading social network among farmers in the United States, where farmers were watching videos to acquire information on products and services for their farm (Figure 3-16).

In Australia, social media is commonly used to develop company images, market products and communicate with customers (ABS, 2017a). Relatively few farms report having a Web presence (6 percent) or a social media presence (5 percent), or both (2 percent), and this limited online presence of farms was also observed by the ABS (2017b). Across all sectors of the economy, agriculture, forestry and fishing had the lowest proportion of businesses with a Web presence in 2015–2016 (12 percent, compared with 50 percent of all businesses) and the lowest proportion of businesses with a social media presence (11 percent, compared with 38 percent of all businesses) (Dufty and Jackson, 2018).

Rural Africa has experienced a particularly high uptake of ICT in the last 34 years (Jere and Erastus, 2015), which is changing the way farmers communicate and the way they access and exchange information, especially among younger generations (Odiaka,

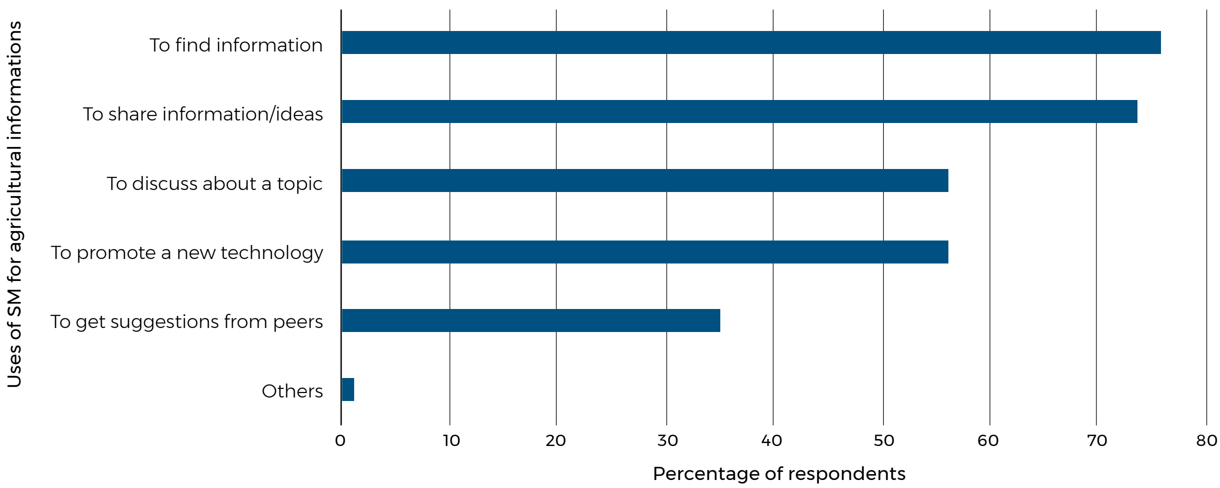
Figure 3-16 Social network use among farmers in the United States, 2017.
Source: MarketingToFarmers.com, 2017



2015). This fast penetration of ICT thus brings new opportunities for African farmers to improve their knowledge and livelihoods (Asongu, 2015; Aker and Mbiti, 2010).

High Internet cost and limited smartphone ownership cause limitations in information flow among farmers and restrict the agricultural support that can be achieved through social networks such as Facebook (Andres and Woodard, 2013). It is mostly farmers from Africa, Asia and other developing countries who are affected by these limitations. Additionally, information dissemination by farmers and agricultural extensionists at professional or organizational level through social media is still low, mainly because lack of awareness (Rhoades and Aue, 2010).

Figure 3-17 Advantages of social media for gaining agricultural information (in percent), 2016.
Source: Bhattacharjee and Saravanan, 2016.



Note: Includes 62 countries.

3.1.5 ICTS FOR AGRICULTURAL EXTENSION AND ADVISORY SERVICES

According to World Bank (2017), the ability of ICT to support agricultural sector development is intensified by rising investment in agricultural research, the private sector's strong interest in development of digital technologies and the upsurge of organizations committed to the agricultural development agenda. If used properly, ICTs provide economic opportunities and foster social and political inclusion, ultimately leading to shared prosperity. In developing countries, growth of ICTs empowers users to communicate and get access to essential information, especially for remotely located individuals and communities (Aker, 2011). Farmers and communities located remotely face difficulties because of the lack of financial capacity and staff. Bell (2015) states that strong public extension services manage to directly reach only 10 percent of the farmer population. In case of limited operating funds, this figure is even lower. Introduction of digital advisory services using digital tools, such social networks and VoIP, will increase the scope of served farmers.

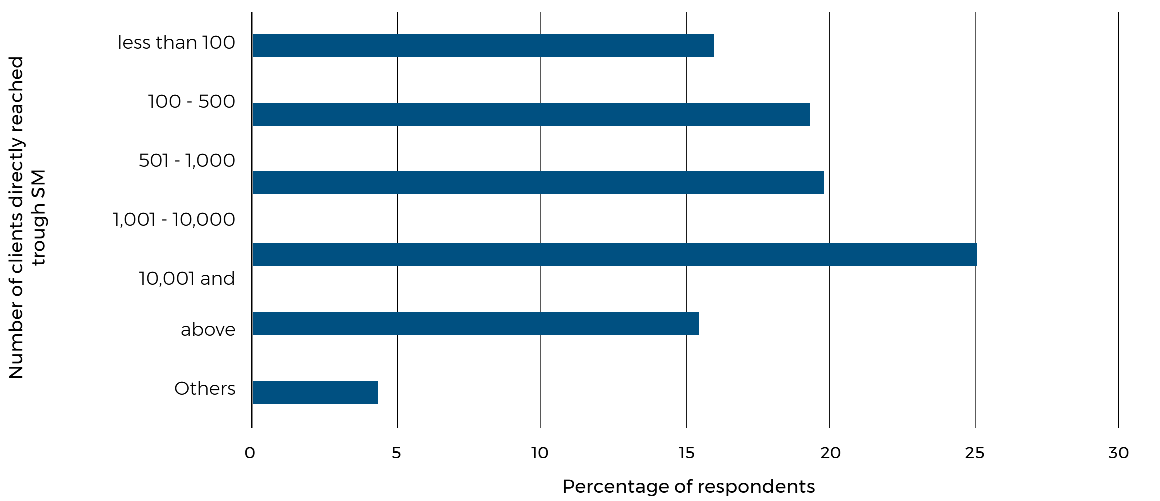
Sulaiman *et al.* (2012) reviewed the use of ICT as a tool for enabling innovation in South Asia and found that its potential as a communication tool had not been adequately utilized. They argue that ICTs could better reach their potential by acknowledging and integrating the roles of intermediaries and their capacities for innovation, and by enabling networks so that communities can make use of the information provided (Sulaiman *et al.*, 2012). A successful application of ICT was achieved by Van Mele, Wanvoeke and Zossou (2010), who found that open-air video presentations facilitated unsupervised learning; unleashed local creativity and experimentation; and built confidence, trust and group cohesion among rural people, including the poor, youth and women.

In Uganda, the goal of Grameen Foundation Community Knowledge Worker[62] is to reach and aid farmers in remote communities through a network of peer advisers, combining smartphones and social networks, by improving their access to accurate information. Simply reaching farmers must be accompanied by transfer of accurate and precise information that is relevant and matches their needs. Although many farmers across the globe use social media to connect with peers and experts and to get access to information and knowledge, extensionists and extension organizations can stereotype farmers: 'Farmers neither are technologically savvy nor receiving qualitative information, thus leading to reluctance in the process of adoption of digital tools' (Diem *et al.*, 2011). Fuess (2011), Newbury, Humphreys and Fuess (2014) and Lucas (2011) reported that irrelevant posts, privacy concerns, stakeholders' conflicting perceptions and lack of capacity in using social media act as constraints to using social media in extension service programme delivery (Figure 3-19).

FAO (2015) reports that Digital Green has produced nearly 3000 videos available in more than 20 languages, reaching more than 300 000 farmers in more than 3900 villages across India, Ethiopia and Ghana. The videos have been screened more than 200 000 times and resulted in more than 370 000 adoptions. However, Bhattacharjee and Saravanan (2016) report that the main constraints for low use of social media in agriculture are use of time allocation and personal privacy concerns over information. Moreover, lack of awareness and social media skills are observed as the main reasons for low social media use by field-level extensionists. In

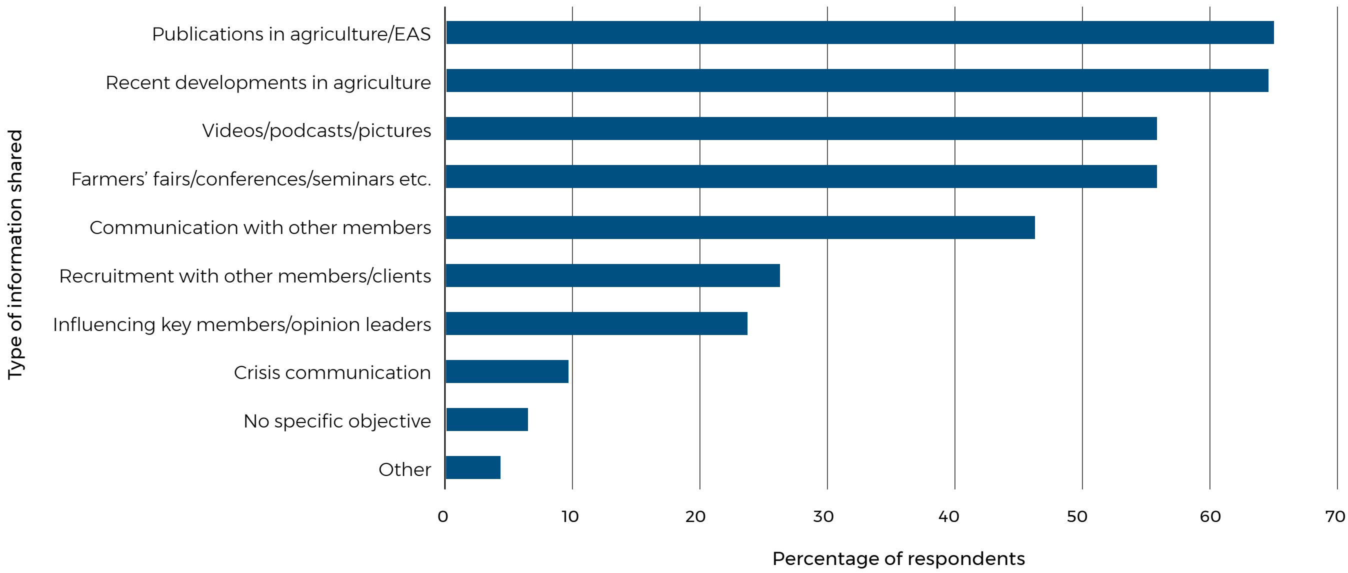
Figure 3-18 Number of farmers directly reached by extension officers through social media (in percent), 2016.

Source: Bhattacharjee and Saravanan, 2016.



Note: Includes 62 countries.

Figure 3-19 Type of information shared by extension officers (in percent), 2016.
Source: Bhattacharjee and Saravanan, 2016.



Note: Includes 62 countries.

developing countries, agriculture extension systems do not employ even low-level ICT in the teaching/learning process. This is a result of poorly trained teaching staff, who lack ICT skills, lack of funds to purchase ICT, unreliable power access, and no supervisory pressure to adopt and use ICT (World Bank, 2011).

Stakeholders in agricultural extension services are often less educated, and use of social media requires both educational and technical literacy. Thomas and Laseinde (2015) reported that extension workers require training in basic skills for use of social media. According to Meena, Chand & Menna (2013), in India, the social network Facebook is most popular among agricultural extension and research professionals. The use of ICT for agricultural extension in Mali and Burkina Faso has historically been approached from the top down, with a particular focus on radio and television shows that have been organized by structured extension services (Bentley *et al.*, 2014). However, Bentley *et al.*, (2014) also cite farmers and local extension officers as having reported that other promising and already existing technologies, such as video on mobile phone and Bluetooth, remain essentially unused in agricultural extension in Mali and Burkina Faso.

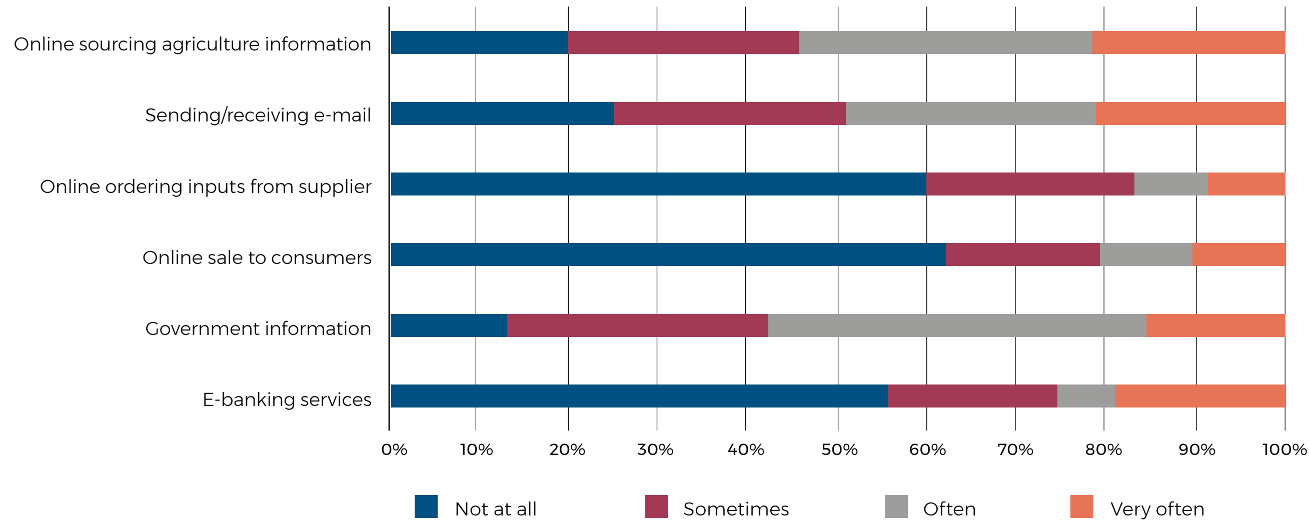
3.1.6 PURPOSE OF FARMERS USING ICT TOOLS

Despite social media and VoIP penetration into the agrifood sector and more frequent use by farmers and rural communities, the content currently offered is not keeping pace with global digital transformation. In the era of AI, Big Data and more advanced technologies, farmers are still only content consumers rather than content producers. Although most farmers are using well-known social platforms, not many of them are using these platforms for agricultural purposes or even e-agriculture services. In some southeastern European countries that are considered as developing, digital content penetration for agriculture and food is at a low level. Not only social media, but also Web sites and SEO (search engine optimization) tools are marginalized by the farmers, despite the IT infrastructure being advanced in these countries.

Farmers in Serbia more often use digital tools to acquire relevant information, for example for accounting purposes (sales, e-banking), than farmers in two other countries included in the survey. Furthermore, government information is often sourced through social and mass media, but rarely through official government Web sites. Digital tools are also important for accessing new markets, and this is especially accurate for the organic farming community in Serbia. Different regions have different needs in terms of the digital content and information required by farmers. In Cambodia, in terms of obtaining farming information via digital tools, 88 percent of farmers were supportive of an agricultural app and 82 percent of a Facebook page in attempts to find information on market prices for their goods, but only 15 percent found the information they sought.[63] In Ghana, most farmers reported looking for a climate-smart weather forecast.[64]

In the United States, a study conducted by *Farm Journal* in 2018,[65] showed that it is not only video content that is beneficial for learning purposes of farmers, but also audio content. Over half of the farmers in the study listened to audio podcasts on their phone at least once a day, while

Figure 3-20 Purpose of using ICT tools among farmers in some southeastern European countries, 2017.
Source: FACE, 2017.



Note: includes Albania, North Macedonia and Serbia.

25 percent of the surveyed farmers listened more than once a day. Figure 3-21 shows that, in 2018, US farmers used their mobile phones mainly for checking commodity prices. The second most common usage was search for agronomic information, followed by reading activity related to agriculture.

3.1.7 USE OF PRECISION AGRICULTURE TECHNOLOGIES

Although smallholder farmers in LDCs and developing countries are trying to leapfrog the process of digitalization and literally "skip the line" in adoption of advanced technologies, such a scenario is only visible for now in developed countries. Application of technologies such as blockchain, AI, robotics and drones are most common among farmers in Canada, the United States, EU and some emerging economies including Brazil, India, China, etc. One of the group of technologies that combine a whole-farm management approach using ICT, satellite positioning (GNSS) data, remote sensing and proximal data gathering for purpose of farming is precision agriculture (PA), which aims to reduce operating costs by preventing farmers from overapplying inputs. Even if input use and operating costs are increased under PA, yields can grow enough to increase operating profits. The capital expenditures needed to implement PA technologies can raise overhead costs, but can also enable farmers to substitute capital and labour for operating inputs (Schimmelpfennig, 2017).

Figure 3-22 summarizes the adoption rates of various PA and agriculture data management tools in Nebraska, Canada in 2015. Producers covered in the survey had widely adopted many available technologies, including

Figure 3-21 Frequency of ICT use for farming activities in the United States, 2018.
Source: Farm Journal, AgWeb Mobile Research, 2018

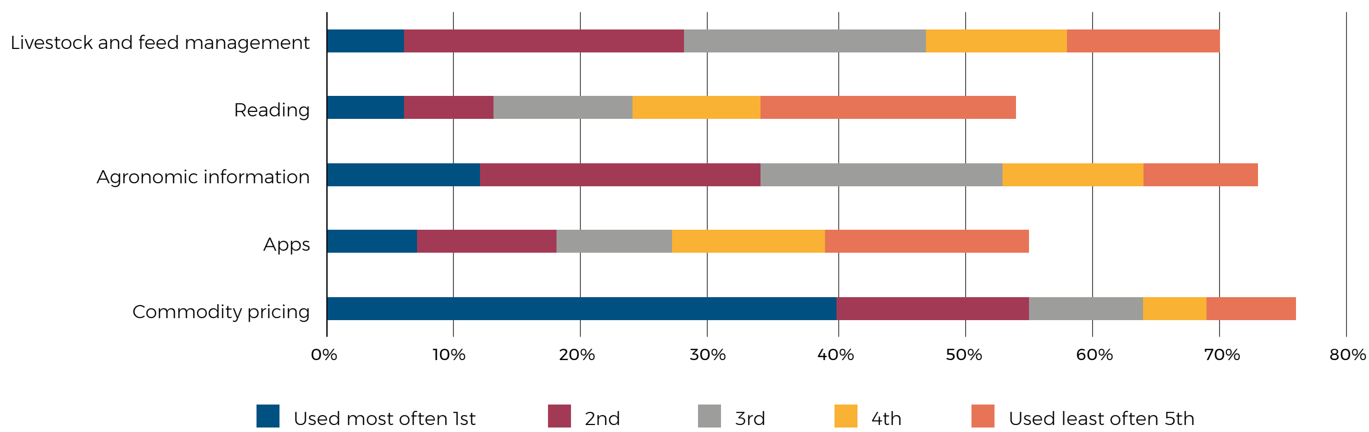
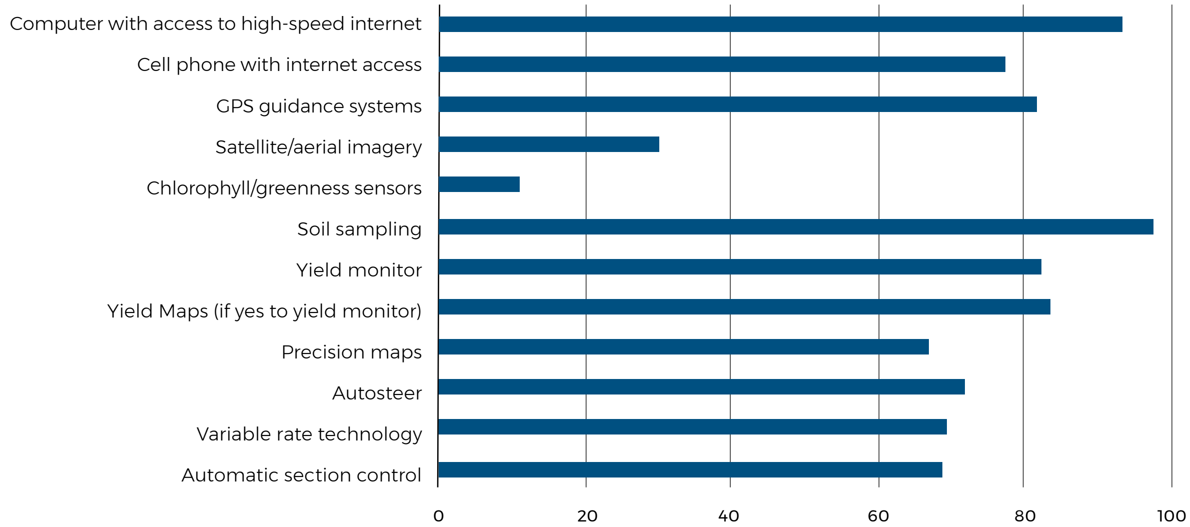


Figure 3-22 Precision agriculture technology use in Nebraska (Canada), 2015.
Source: Castle, Lubben and Luck, 2015.



soil sampling (98 percent) and computer high-speed Internet access (94 percent). Yield monitors and maps and GPS guidance systems were the next most common practices with high adoption rates of more than 80 percent. Yield monitors and maps may be a prerequisite for any additional PA practices. These are also a first step for building historical data for further analysis.

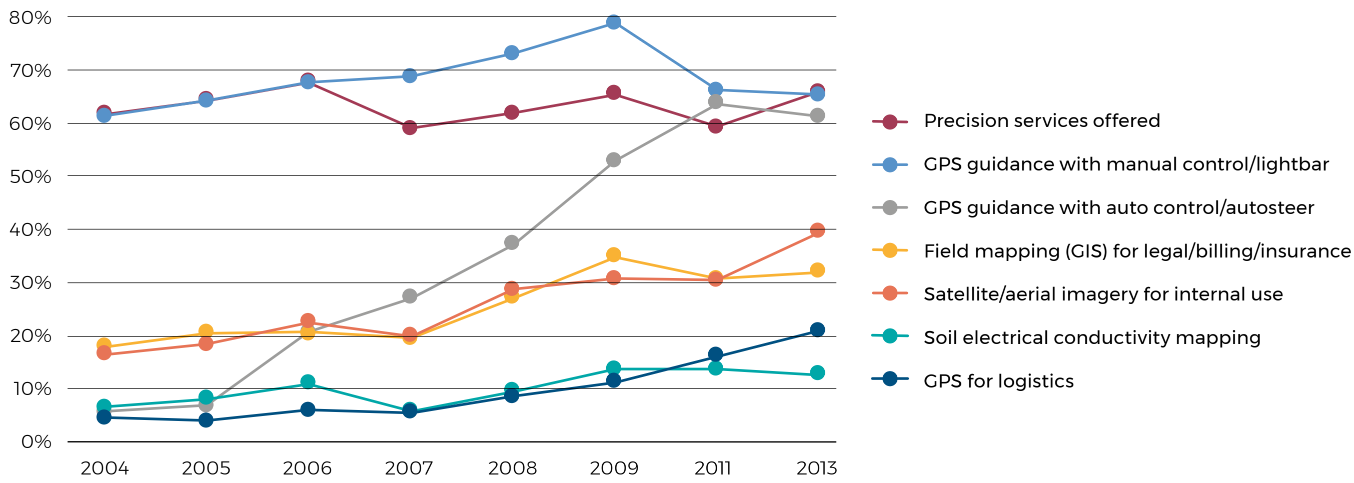
For PA, guidance systems are crucial for improving field efficiency and reducing driver fatigue. Guidance systems facilitate the use of auto-steer and automatic section controls, which were also widely adopted among survey respondents. Variable rate (VR) technology is also widely adopted at 68 percent among survey respondents (Castle, Lubben and Luck, 2015.). The study also shows that producers use various farm software during farm operation and for analysing and production and management decision-making. Figure 3-22 provides insight on the uses of software. Software use for yield mapping was most common, followed by use of VR nutrient and fertilizer application as well as VR seeding. Furthermore, there is significant software use for soil sampling and record tracking.

PA is most advanced among arable farmers, particularly with large farms and field sizes in the main grain growing areas of Europe, the United States and Australia, and where a business model to maximize profitability is the main driver. Adoption of PA and its use have increased over the years at a global level. Perhaps not all the technologies are applicable for smallholder farms, but decreasing costs of digital technologies and increasing knowledge and awareness among farmers means that those technologies that are applicable are being applied more often. To date, this trend of adoption among smallholder farms is occurring among smallholders located in developed and developing countries.

PA has become part of standard operating procedure for many US farming operations. While the efficiencies and per-hectare savings offered have been confirmed by research and growers alike, there remain barriers to operating the sometimes not-so-user-friendly technologies. Figure 3-23 shows the use of precision technologies over time in the EU. Precision services and manual control guidance systems have been the most used and there has been rapid adoption of auto-steer guidance systems. Remote sensing services have increased as well as soil electrical conductivity mapping and GNSS for logistics.

Detailed statistics concerning how business is organized at the EU level are scarce, and little information is shared by multinational dealers both because of confidentiality and because of the large heterogeneity of cases found in Europe (European Parliament, 2014). Holland *et al.* (2013), in their US dealerships survey, found that more than 80 percent also provided custom services. These figures are likely to be indicative for Europe. Major consolidation across the retail and wholesale industries (see Section 3.3.2), and trends in solutions management for the grower add enormous complexity to the agricultural market. However, these interactions will enable the distribution channel to identify solutions to fit their individual business model and provide a higher return on invested capital. Retailers, agencies and farmer dealers will continue to be the touch point for the grower. As a result, the industry's fertilizer, seed and crop protection segments may change dramatically.

Figure 3-23 Use of precision technology over time on farms at EU level, 2004-2013.
Source: European Parliament, 2014.



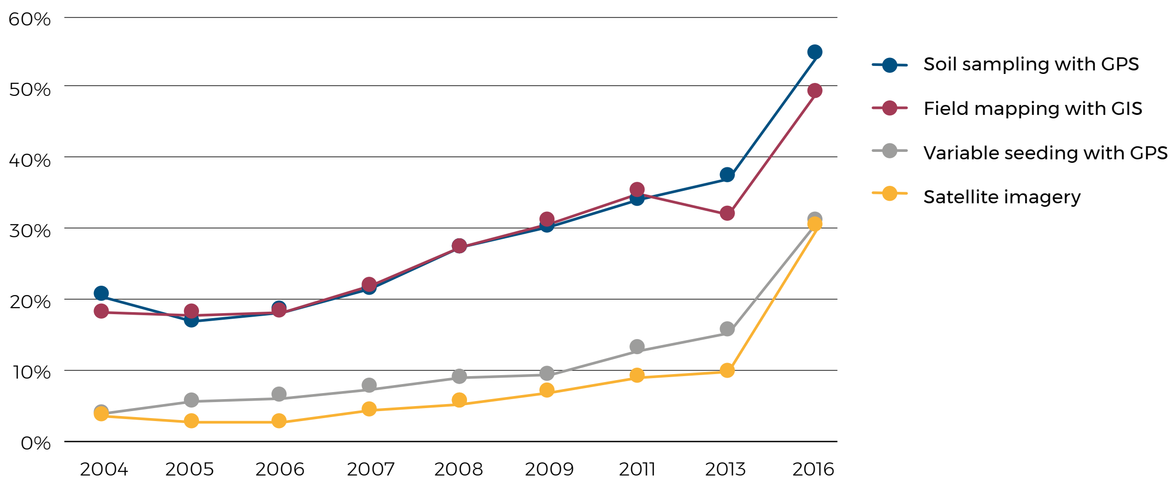
However, based on data available, contract services in EU-28 have increased rather rapidly but they are a function of the available funds of farmers; that is, these services are likely to be reduced in years of poor returns. Soil sampling with GNSS and field mapping are the two most popular services, but yield monitor data analysis and satellite imagery use has increased in the last few years and show an even greater rise forecast to 2016. The adoption of additional precision services over time (Figure 3-24) shows a steady increase with an expected rapid increase towards 2016.

Figures 3-23 and 3-24 illustrate that PA could play a substantial role in meeting the increasing demand for food, feed and raw materials in EU-28, while ensuring sustainable use of natural resources and the environment. Nevertheless, there are challenges to adoption of PA in the EU in terms of the sizes and diversity of farm structures. An assessment of the potential actions to support adoption of PA by medium and smaller sized farmers is identified as an important enabling step.

3.1.8 CONCLUSION

Education and income levels are strong determinants, not only of whether or not people use the Internet, but also of how they use it. Internet users with higher levels of education use more advanced services, such as e-commerce and online financial and government services, to a higher degree than Internet users with lower levels of education and income levels, who use the Internet predominantly for communication and entertainment purposes. The connectivity gap continues to close: in the coming years, it is expected that a billion people will start using mobile Internet, making over 60 percent of the world population connected. Despite the fact that almost every second person in the world is

Figure 3-24 Precision agriculture services offered over time in EU, 2004-2016
Source: European Parliament, 2014.



using the Internet, this number is significantly lower in LDCs, being only one in seven people. This is number is emphasized among youth. Those from higher income countries tend to use the Internet for a broader range of activities compared with youth from LDCs and developing countries. This gap is even deeper in LDCs, where in most of the countries, the proportion of male Internet users is higher than female Internet users. Access to the Internet is a critical component of new technologies, but universal Internet access remains an issue.

Mobile phone users are using their devices for different activities, mostly differentiated based on age, gender and personal preferences. The most common activities are phone calls, sending text messages and e-mails, making videos and social networking, but the pattern of mobile usage varies based on age and gender, and also differs across urban and rural regions. Mobile agricultural apps show significant potential for modernization of the agricultural sector, in both developed and developing countries, and as mobile phones are the most affordable and accessible ICT tools, they will be the game-changers in the agriculture and food sector, supported by the existing social platforms and VoIP networks. The main obstacles to contact with rural communities and farmers is the high Internet cost and limited smartphone ownership, causing limitations to information flow among farmers and restricting the available support. With the ability to make better decisions about their crops and farms, farmers mostly in developed and some developing countries use PA approaches to increase yields, protect the environment and improve their livelihoods.

Regarding the main constraints to adoption of advanced digital technologies, the lack of standards and limitations on the exchange of data between systems prevents adoption of machinery and instrumentation from different brands and companies. In addition, there is a lack of independent advisory/consultancy services, as there is a lack of validated agronomic models to help make decisions on the investments required.

3.2 Digital skills among rural population

Digitalization will lead to automation of routine work, hence there will be increased demand for those with ICT skills who are able to make full use of digital devices, process the informational output and further develop programmes and applications. This requires not only literacy skills for basic communication, but also higher order skills in manipulating, interpreting, displaying and communicating data. In other words, today's youth population which has not achieved basic literacy and numeracy skills while schooling must move quickly to master the skills necessary for processing information and digital data. ICT is developing at a tremendously speedy pace, leading to increased demand for fast adoption and learning of the same. 'In an extremely dynamic global market where products and processes change rapidly, a basic education in literacy and numeracy as well as fast and efficient continued learning are critical' (UNDP, 2015).

3.2.1 GLOBAL TREND ON DIGITAL SKILLS

The WEF (2016) estimates that 33 percent of the jobs that will be performed in 2020 do not yet exist, claiming in a report that the skillsets required in both old and new occupations will change in most industries and transform how and where people work. At least 133 million new roles generated as a result of the new division of labour between humans, machines and algorithms may emerge globally by 2022. There will also be strong demand for technical skills such as programming and app development, along with skills that computers cannot easily master such as creative thinking, problem-solving and negotiating (WEF, 2018). The WEF (2018) also estimates that more than half (54 percent) of all employees will require significant reskilling by 2022, but the problem is likely to be even more acute in some regions. For example, Eurostat (2017) show that around 37 percent of workers in EU-28 do not have even basic digital skills, far less the more advanced and specialized skills companies need to successfully adopt digital technologies.

In EU-28, only 26 percent of the population have low overall digital skills, but this figure varies among different countries, ranging from 5 percent in Luxembourg, to 45 percent in Bulgaria and 46 percent in Romania. In eight EU countries, 30 percent or more of the population have no digital skills. In Italy, this figure equals almost 18 million people without digital skills. For effective functioning in the digital society an individual needs more than just low-level skills, such as sending e-mail. Almost half of the EU population, namely 40 percent can be considered as digitally insufficient, having either low digital skills or not using the Internet. Again, the figure varies among different EU countries, and 17 Member States have rates higher than this. According to Digital Agenda Scoreboard (2015),[66] in Romania 80 percent of the population does not have the digital skills they need to function effectively in the digital world.

In addition, in some countries from Southeast Europe such as Kosovo (UNSCR 1244/99),[67] almost three-quarters of the population have low overall digital skills, followed by North Macedonia, Turkey, Serbia and Montenegro,

Figure 3-25 Digital skills among active population (rate 1-7 best), 2017.

Source: World Economic Forum, 2018.

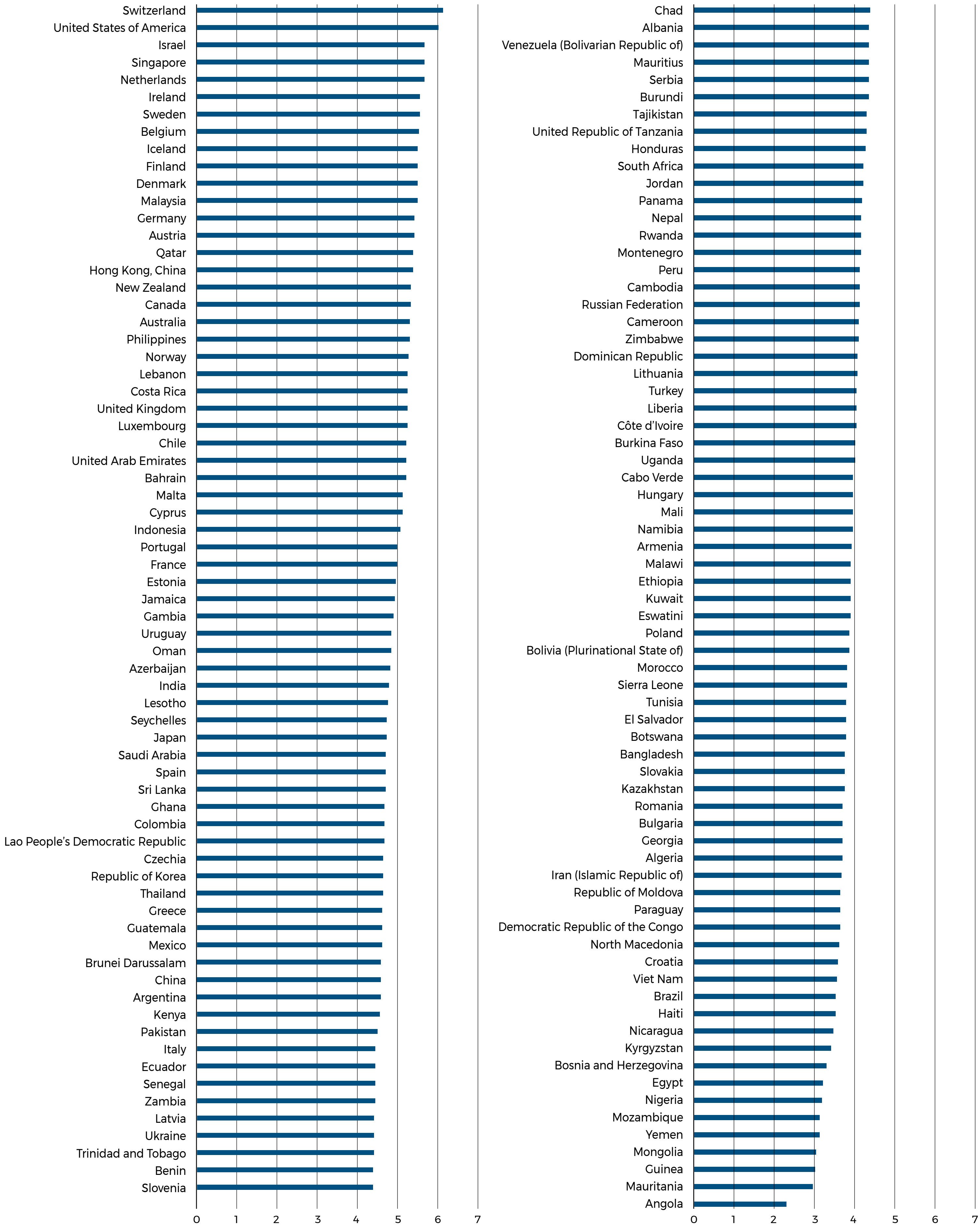
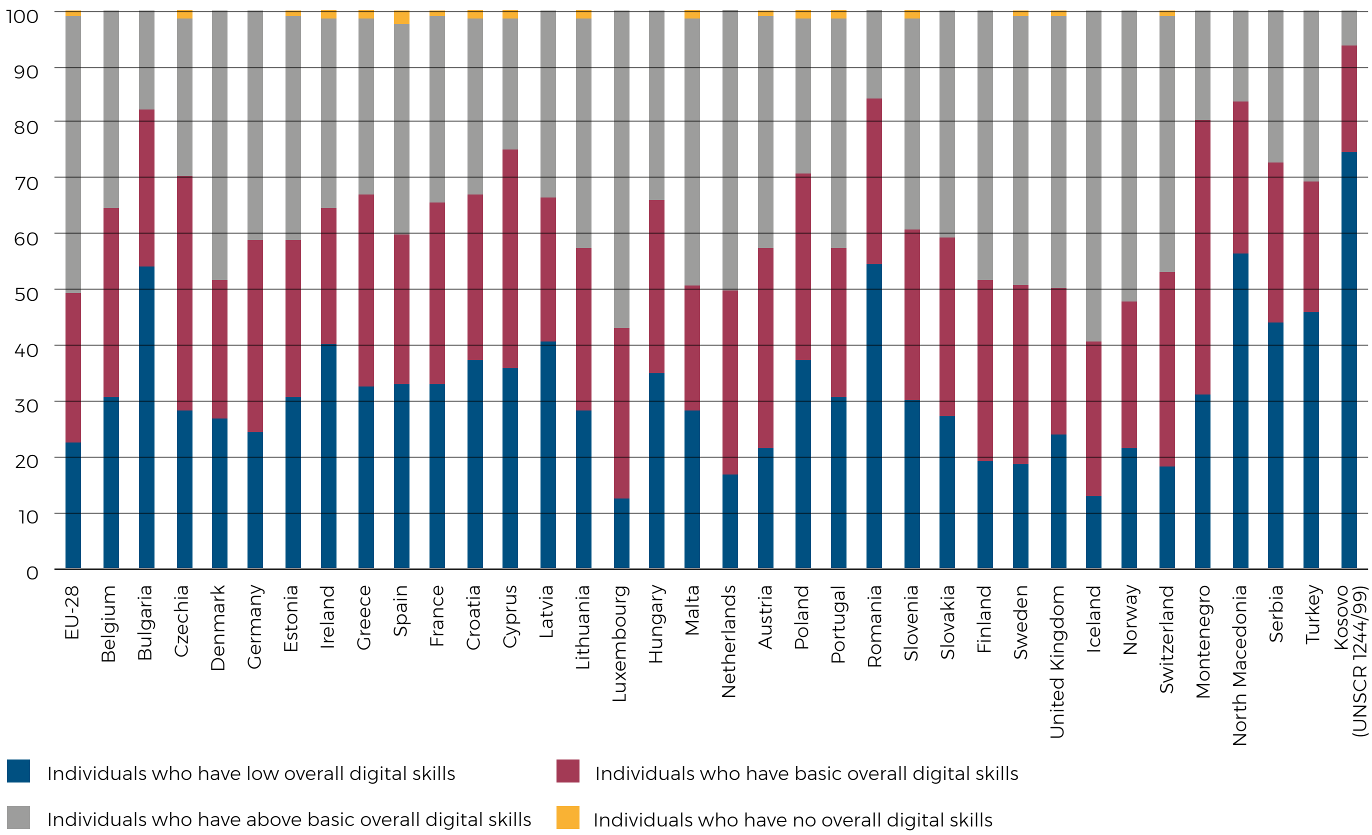


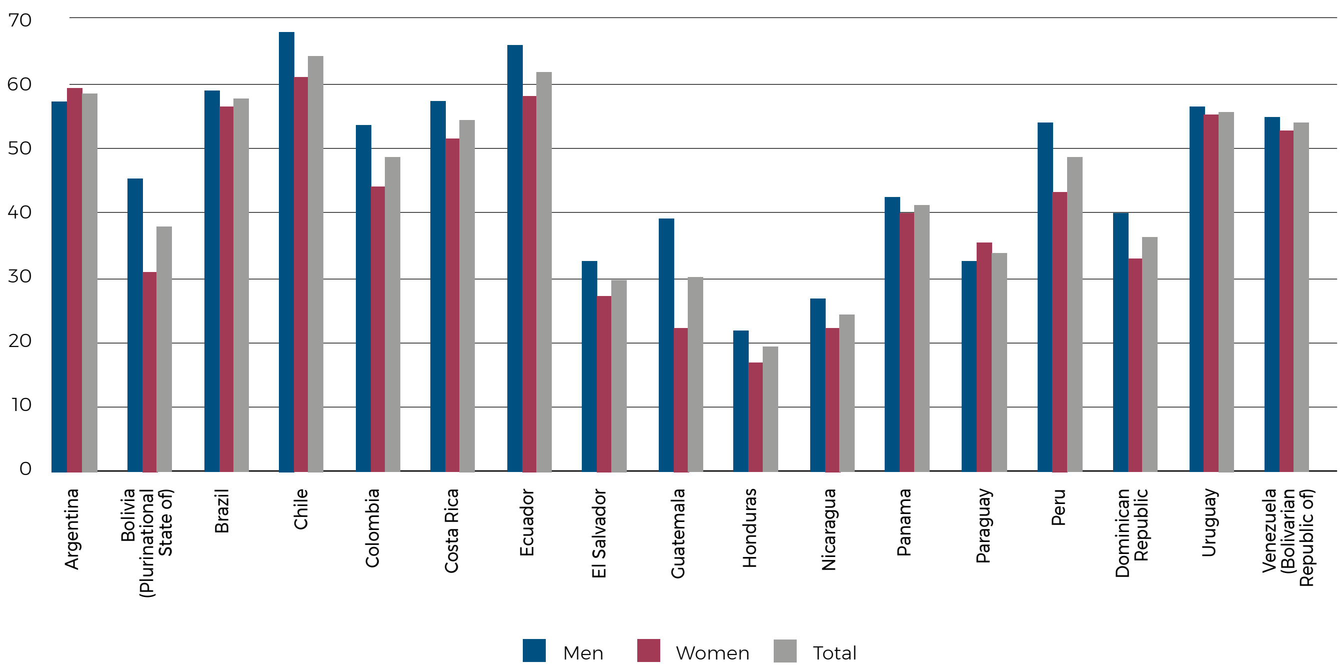
Figure 3-26 Digital skills of the EU-28 and some other countries' population (percent individuals), 2017
Source: Eurostat, 2017a.



respectively. Below the EU-28 average are only three non-EU countries, Iceland, Switzerland and Norway.

As Figure 3-27 shows, the gender gap in basic digital skills, or at least in basic function like sending e-mail, in Latin America and the Caribbean is higher than in EU-28. Men more often use e-mails then women. Only in Argentina do women send e-mails more frequently than men. A wider gap is present in Bolivia and Honduras.

Figure 3-27 People who frequently use e-mail by gender in Latin America (percent of population), 2015.
Source: ECLAC, 2015.



3.2.2 DIGITAL SKILLS GAP BETWEEN URBAN AND RURAL AREAS

Rural areas are more affected by limited access to high-speed Internet than urban areas. However, over half of rural business owners said they face a variety of skills-related obstacles to adopting digital technologies to unlock more growth, such as recruiting people with appropriate skills to finding training for their existing workforce. In rural areas there is a lack of skilled tech workers, hence rural communities have limited pools to hire from compared with urban areas. RESURC (2018) reported that 14 percent of business owners have difficulty accessing appropriate external digital training for the existing workforce ,and one in five said their existing workforce lacks skills and that it is a struggle to recruit people with appropriate digital skills.

Moreover, IT professionals often seek higher wages than rural businesses can afford, leading to limited local tech support. Access to training is crucial for tech skills adoption among employees. New technologies require workers who perceive and apply these digital options. Usage of blockchain to manage the supply chain of small farms for example, would be a boost for these businesses' economic success.

Figure 3-28 summarizes the ruralurban skills gap. People residing in urban areas possess more technical skills compared with people from rural areas. The latest report from ITU (2018) highlights a different skills gap. For example, there are 13 percent more skilled people that can copy or move a file or folder in urban than in rural areas, and 17 percent can send e-mails with attached files. Although mobile phones use is increasing among rural populations, and social media penetration is also increasing, skills in downloading and installing software lag behind those of urban residents. As writing computer programs is still relatively new, and mostly known only among the youth population, it is expected that neither rural nor urban residents are likely to possess such skills.

It is clear that introduction of ICT within the education process leading to higher e-literacy, and accessible and affordable digital tools and Internet, results in better performance in terms of digital skills. However, rural areas lag behind in the process of gaining such skills. In EU-28, the populations of rural areas are more likely to lack basic knowledge and technology skills. This means that even if the digital infrastructure is built, rural areas may remain underexploited in terms of service provision. Wilson *et al.* (2018) reported that rural populations in the United Kingdom face skills-related obstacles, creating an issue for business owners in these areas, as it is generally harder to adopt digital for more growth, harder to recruit a skilled workforce than in urban areas, and there are also challenges in terms of finding training for existing workforces.[68] Another challenge is the gender gap, which alongside the degree of urbanization, has an impact on the process of developing a digitally native EU society. From Figure 3-28, it can be seen that gender gap is narrow but present in EU-28.

Digital skills are becoming an essential element of modern farm management as there are increasing digital technologies focused on the agricultural and food sector on the market. There has been an increase in the demand for farmers and labour force with digital skills, but there is huge skills gap in the sector, which is felt even more acutely in rural areas, no matter whether in developed countries or LDCs (McKinsey & Co., 2016c).

Figure 3-28 Average proportion of the population in rural and urban areas with a specific digital skill, 2017.
Source: ITU, 2019.

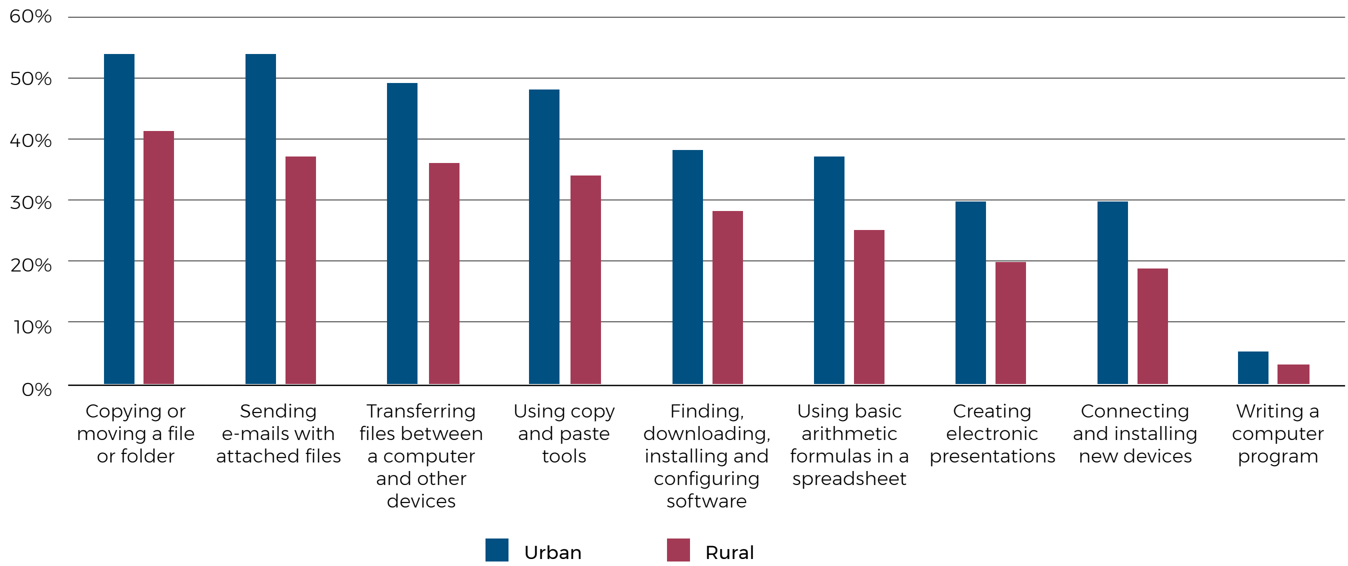
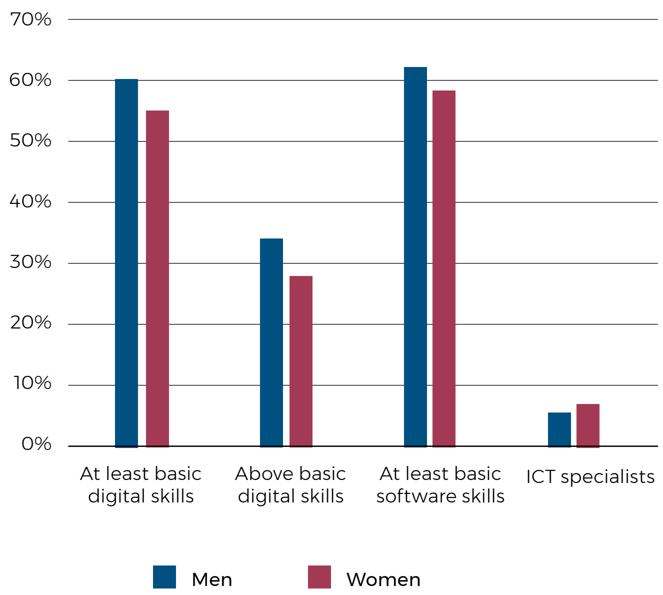


Figure 3-29 Gender gap in digital skills in EU-28, 2018.
Source: Eurostat, 2019.



3.2.3 CONCLUSION

The digital transformation is changing structurally the labour market and the nature of work. There are concerns that these changes may affect employment conditions, levels and income distribution. Alongside investment in technology, we need investment in skills and knowledge, to prepare for the future. The need for new multidisciplinary digital skills is exploding. The skillsets required in agrifood sector will change and transform how and where people work. This may affect female and male workers differently and transform the dynamics of the agrifood industry gender gap. Digital skills are a concern in both developed and developing countries. It is obvious that those countries having introduced ICT within the education process have higher e-literacy and accessible and affordable digital tools and Internet, and will have better performance on digital skills. However, rural areas lag behind in the process of gaining those skills. In response, development of a digital skills model is required for farmers in which they can learn the skills to quickly analyse, assess and implement the best actions, solutions and technologies for their farm business. Digitalization is having a major impact on the labour market and the type of skills needed in the rural economy and is redefining the role of farmers and agripreneurs.

3.3 Digital agripreneurial and innovation culture

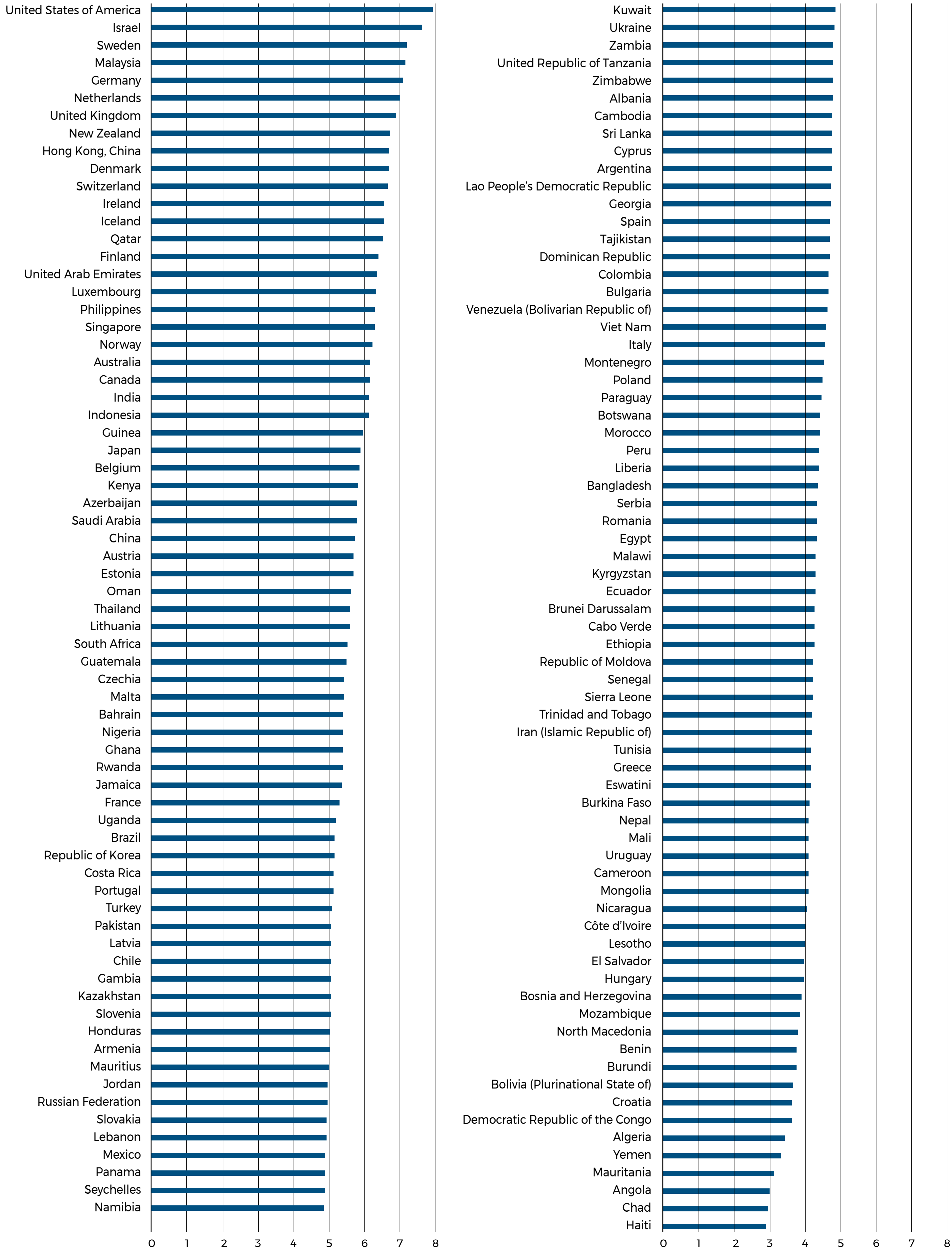
Creating a digital agripreneurial culture is a life-long political and practical process. It starts from preschool and elementary schools and upwards. The components needed for creating a long-term digital agripreneurial culture are risk-taking, robust relationships based on trust between all stakeholders, financial opportunities, professional services, a sustainable digital ecosystem, skills and attitude of sharing and generosity or so-called "open innovation".

In general, digital entrepreneurship embraces all new ventures and the transformation of existing businesses through novel digital technologies. In the digital era, enterprises are characterized with high intensity utilization of new digital technologies (particularly social, mobile, analytics and cloud solutions) to improve business operation, invent new (digital) business models, sharpen business intelligence, and engage with customers and stakeholders through new (digital) channels.[69]

Consequently, we are witnessing an impressive number of initiatives across the globe to foster acceleration of digital entrepreneurial activity related to the creation and development of "digital start-ups", and more recently with their growth to scaling-up phases. This trend is visible in the agriculture and food sector. Moreover, twenty-first-century farmers design business plans, scout for funding, enjoy new farming enterprise incubators and attend scientific conferences. Youth generation farmers are more risk-takers and possess more entrepreneurial spirit. For example, in Italy alone, over 12,000 agricultural start-ups were created in 2013 by young men and women aged 25–30 (Coldiretti, 2018). In Africa by the beginning of 2018, 82 agritech start-ups were recorded, with 52 percent of these ventures launched in the previous two years (Disrupt Africa, 2018).

In the digital age, building an entrepreneurial culture generally is not related to a country's GDP or geographical region or location, as e-commerce and digital platforms are easily accessible, and it is easy to foster an entrepreneurship culture journey. Inevitably, developed countries are leaders in enabling the entrepreneurial environment, but also less developed countries, such as Guinea, Rwanda, Zambia in Africa or Turkey and Armenia in Central Asia are keeping pace and seizing the opportunities of the digital age.

Figure 3-30 Entrepreneurial culture (score 0-100), 2017.
Source: WEF, 2018.



3.3.1 GLOBAL TRENDS IN AGRITECH ENTREPRENEURSHIP

Today, the main problem for digital agripreneurs is not use of technology, nor how the technology is deployed, it is the strategy, the leadership skills and new ways of thinking and mind-set. In exploring how to solve these issues, there are five broad domains of strategy: to rethink customers, to rethink competition, to rethink data, to rethink innovation and to rethink value. The farmers must ask themselves the following question, 'What is my value to the marketplace?'.

Many farmers are already excellent managers, and many possess the agripreneur spirit. As 'price takers', many farmers have developed outstanding abilities to make the most of their resources. But being 'price takers' suggests that these farmers are not innovative, do not take risks and lack the drive that is usually associated with an entrepreneurial spirit (Kahan, 2012). To conclude, not all farmers can be entrepreneurs and, vice versa, not all entrepreneurs can be farmers. However, to build a sustainable digital ecosystem we need all stakeholders on board. Digital technologies are those that will reshape the future of the agrifood value chain.

Indeed, the increased use of digital technologies in agriculture opens up new markets and possibilities. For more demanding and sensitive end consumers, farmers can create customized production chains as per a customer's request. This is where start-ups that create innovative products with intelligent systems can benefit. These systems document the whole production process, from crop cultivation, fields, mills and processing plants in a way that customers can understand and trace. The development of novel products also continues in the agricultural engineering sector. There is the expectation that innovative solutions will continue, providing farmers with opportunities to feed the world while operating a profitable business. For example, agricultural GPS systems (e.g. AGCO, Claas, CNH, John Deere, Krone, Lemken, Rauch, etc.) can contribute to reductions in the quantity of fertilizers and pesticides used.

Digital agriculture is not only attractive to big multinational companies, it is also attractive to youth engaged in agriculture, as they have already identified income generation opportunities through enterprises that deliver digitally empowered services to farmers and other actors in the agricultural sector. In other words, the advent of the digital age in the agricultural sector has changed the face of the agriculture and food sector and now forms a segment for attracting young people, especially in emerging economies and developing countries.

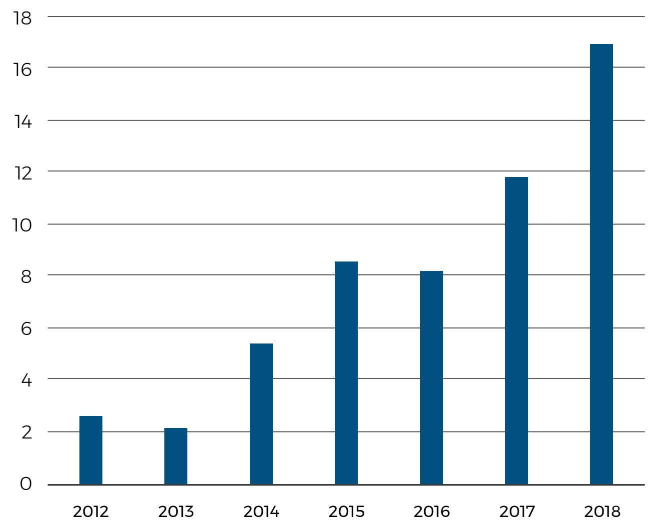
Agritech start-ups, those innovating all the way from farm-to-fork, raised US$16.9 billion in 2018, a 43 percent year-over-year increase, in line with the overall venture capital (VC) market globally. In contrast to all VC industries there was an 11 percent increase in deal activity, particularly at the seed stage where levels have contracted in other industries. Although the United States still dominates the sector, China, India and Brazil contributed some of the year's largest deals and the United Kingdom, Israel, and France complete the top seven by number of deals (AgFunder, 2018).

According to NASSCOM (2018), the Indian Government specifically supports agritech start-ups through its "Start-up India" programme. In 2016, more than 350 agritech start-ups raised US$300 million in investment globally, out of which Indian investment accounted for 10 percent. In Asia, China had 10 deals totalling US$427 million and four Japanese deals raised US$8.9 million (AgFunder, 2018). Over the course of this period, over US$19 million has been invested into African agritech start-ups, with annual fundraising figures growing rapidly. The amount of funding in 2017 grew by over 121 percent on the total for 2016 (Disrupt Africa, 2018). In particular, Nigeria emerged as the premier investment destination on the continent in 2018, with 58 start-ups. South Africa fell behind with 40 businesses, while Kenya ranked third in terms of the number of start-ups (Disrupt Africa, 2018).

All these start-ups are creating the global future of the agriculture and food sector. Investing in such initiatives is a way to close the digital divide and empower rural communities and smallholder farmers. These initiatives are not just serving farmers, but also creating job opportunities for rural areas. For example, Indian Aibono[70] is the first smart farming collective and this start-up turns around the fortunes of small farmers with the Internet and AI shared services. Pegged as Agri

Figure 3-31 Annual funding agritech start-ups between 2012 and 2018, in US$ billion

Source: AgFunder, 2018.



4.0, the company provides PA technologies backed by real-time synchronization of supply and demand. The company has about 60 employees and will be 100-strong by the end of the year 2019. In Uganda, the digital platform for financial inclusion called Ensibuuko[71] is an example of a young social enterprise that become a profitable company, creating disruptive digital solutions to make financial services easily accessible to unbanked and underserved people. Through the social enterprise Hello Tractor[72] in Nigeria, low-income farmers can measure the fertility of their soils with a mobile phone. Such powerful digital tools must be given more attention, not only because of the broad scope of services they provide, but also because these are being developed by young professionals.

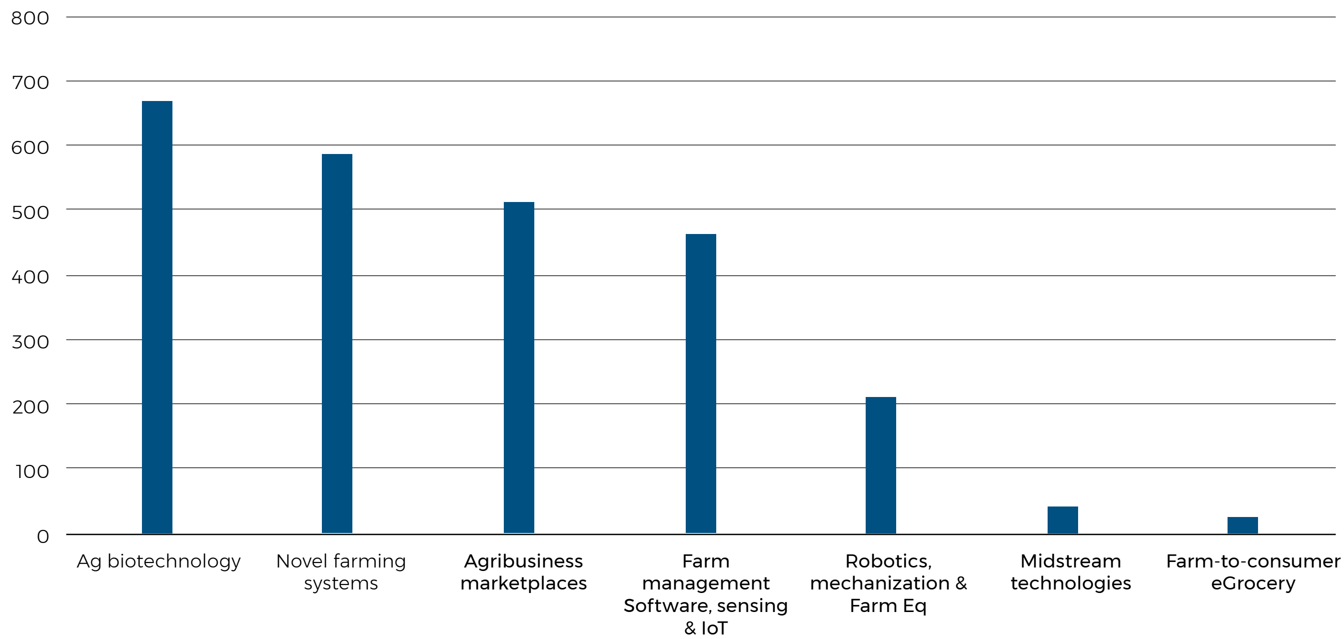
3.3.2 INVESTMENT IN DIGITAL AGRICULTURE

Mega funding rounds from companies such as Bayer, DowDuPont, BASF, etc. are redefining the agritech investment landscape as we move forward in the digital age, and these companies are looking to scale in a sector that has around US$3 trillion value at the farm gate, and multiples of that downstream. Currently, Facebook's technologies are being used by BASF to identify weeds,[73] Cargill is brewing a sweetener crop from Paraguay called Stevia in containers in Switzerland; Amazon has bought Whole Foods, an organic food retailer, while Google and China's Alibaba are advising farmers and delivering groceries to customers.[74] In turn, a more diverse universe of investors supporting these companies is signalling a sea change in agritech investment. With indoor farming, disruptive retail, along with genome and microbial tech all vying for the big dollars, there is understandable angst for the "have nots" trying to attract capital to compete with the "have mores".[75]

Based on a global annual crop production value of US$1.2 trillion in 2015 and bottom-up estimation on technology-driven yield improvement of 70 percent, it is estimated that globally, possible value generation by 2050 will reach US$800 billion, if all of the technologies are fully adopted. The actual value capture will depend on how the competitive environment evolves (Goldman Sachs, 2016). The evolution of the market will be driven by the gradual introduction of more advanced and more interconnected digital solutions (e.g. drones, IoT, robotics, PA, blockchain, AI, etc.), and by the rise of Big Data analytics.

According to Roland Berger (2015), the global PA market will grow 12 percent by 2020, while the total market value will cross US$5.5 billion by then. The precision farming market in Asia and the Pacific region is still in the early stages of the adoption life cycle (20 percent), but it is expected to grow in double-digits between 2016 and 2022. India, Australia, China, and Japan have the highest growth rates in the precision farming market, with large-scale adoption of advanced farming solutions such as soil mapping, yield mapping, variable rate technologies (VRT) and guidance and steering systems.[76] The adoption of IoT solutions for agriculture is constantly growing too. BI Intelligence (2016) predicts that the number of agriculture IoT device installations will hit 75 million by 2020, growing 20 percent annually.[77] According to IDC (2019), total corporate and government spending on blockchain should hit US$2.9 billion in 2019, an increase

Figure 3-32 Digital agriculture investment by category 2017, in US$ million.
Source: AgFunder, 2017.



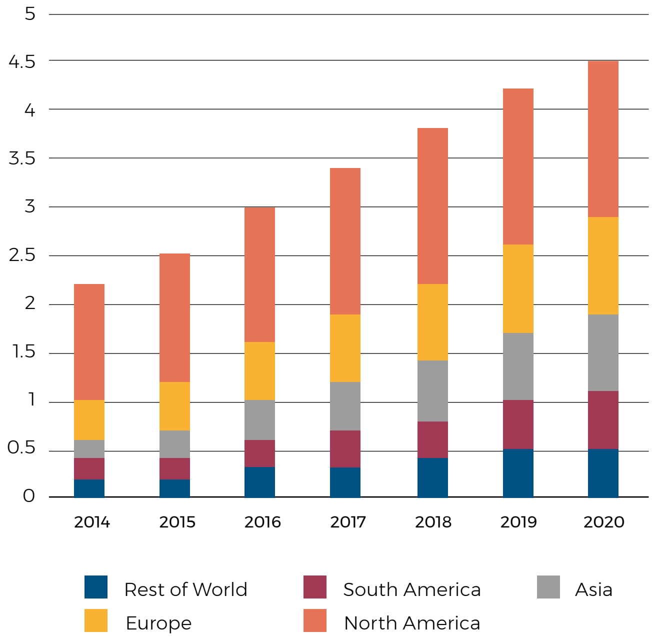
of 89 percent over the previous year, and reach US$12.4 billion by 2022. The agricultural robot market will reach US$16.3 billion by 2020 (ReportsnReports, 2014). According to PwC (2017), the current global market for drones in agriculture stands at US$32.4 billion. All this growth is mostly attributed to the rapid uptake of PA applications in developing countries (especially China, India and Asia and the Pacific region) and the uptake of sophisticated solutions in the most advanced areas (United States, Europe and Australia) (GSA GNSS, 2018).

North America is currently the most technologically advanced region and the heartland of PA, with the highest installed base, followed by Asia and the Pacific region. In Europe, western and eastern countries move at different pace and maturity level regarding adoption of PA-based solutions. Western Europe boasts a highly developed PA sector, with increased output and mechanization, which is mainly driven by increased cost efficiency needs (GSA GNSS, 2018). In the Netherlands, for instance, 65 percent of the arable farmers were using PA technologies in their farming activities in 2016.[78] The growth in the adoption of PA in countries such as the United Kingdom has shown that between 2009 and 2012 the proportion of farms using PA increased. The increase for GNSS was greatest, from 14 percent to 22 percent, for soil mapping from 14 percent to 20 percent, for variable rate application from 13 percent to 16 percent and for yield mapping from 7 percent to 11 percent (European Parliament, 2014). Eastern Europe, on the other hand, starts at a lower level but grows at a greater pace, driven by the need for increased output.

Compared with high PA-adoption countries (e.g. Japan, Australia, South Korea), market trends in eastern Europe and other highly developed countries show that these countries also place high focus on adoption of novel technological solutions, including drones, optical sensors and future ICTs like 4G and 5G, while seeking integration of and with existing technologies into complete farm management systems (GSA GNSS, 2018). Walter *et al.* (2017) observe that there is increased use of radio frequency identification (RFID) technology in central and northern European countries, such as Germany, Denmark and Sweden. Another technology in digitalized agriculture is robotics. Cost is the main barrier for advanced technology like robotics and its reception is low all over the world. It is mainly used in the dairy industry for automated milking, but mostly in developed countries, with 30 percent of farms in the Netherlands and 2 percent of farms in the United States using this technology.

The guidance systems offer several benefits and they are well accepted by European farmers. Investments are generally lower than for other PA technologies, the risk

Figure 3-33 Market estimation of precision agriculture 2014–2020, in billion.
Source: Roland Berger, 2015.



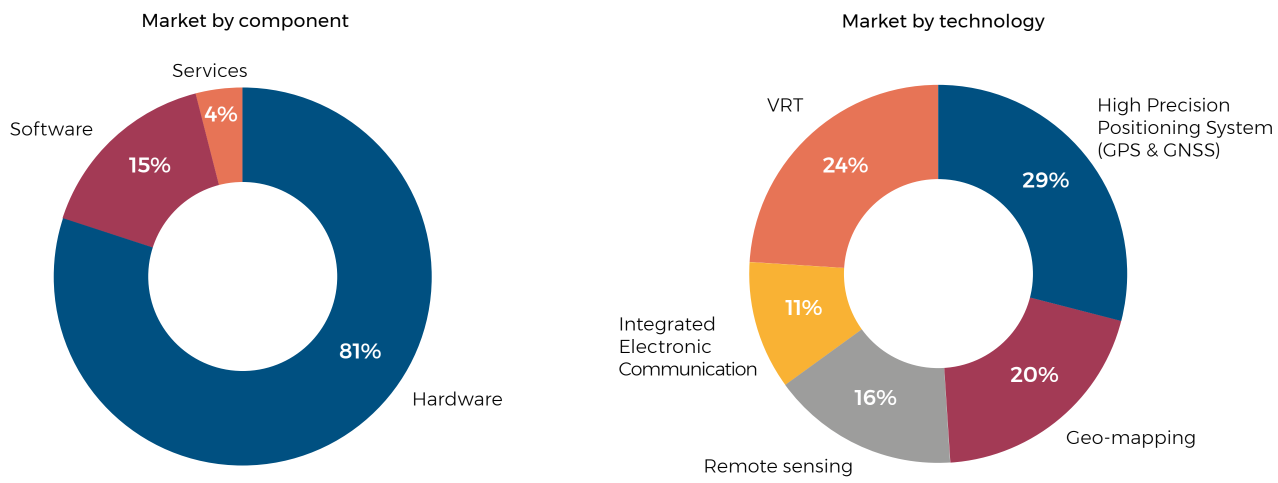
Note: Market estimation includes software (e.g. data management systems, advisory services) and hardware (e.g. automation and control systems such as: guidance steering, displays, flow control devices, sensing and monitoring such as yield monitor, soil sensors).

is lower, and the results obtained are more convincing for the farmer. Automatic guidance systems have significantly developed in the last decade in the United States, Australia and in Europe (Heege, 2013).

The GNSS market in agriculture is relatively small, only expected to be 1.4 percent of the cumulative core revenue for 2012–2022. The GSA GNSS Report (2013) indicates that there is increasing use of PA not only in developed countries but also in developing countries. Auto-steering and VRT are growing faster than previously estimated and could provide nearly 80 percent of the GNSS revenues from agriculture. In Europe future growth is expected to be increasingly driven by uptake of GNSS technologies in central and eastern Europe where penetration is currently low (European Parliament, 2014).

In general, PA requires expensive equipment. A drone costs at least US$1000. An Internet-enabled tractor costs around US$350 000. These are prohibitively high costs for a farmer who may live on less than US$2 per day. Many farmers do not have access to credit to invest in higher productivity tools.[79] Given their high exposure to risk and limited ability to manage shocks, smallholders often prefer to choose cheaper and low-return production options over technology-intensive ones, in this case smartphones. Indeed, telecom operators can play a crucial role in the agricultural sector and offer greater

Figure 3-34 Precision farming market, by component and technology in 2015.
Source: Global Market Insights, 2018.

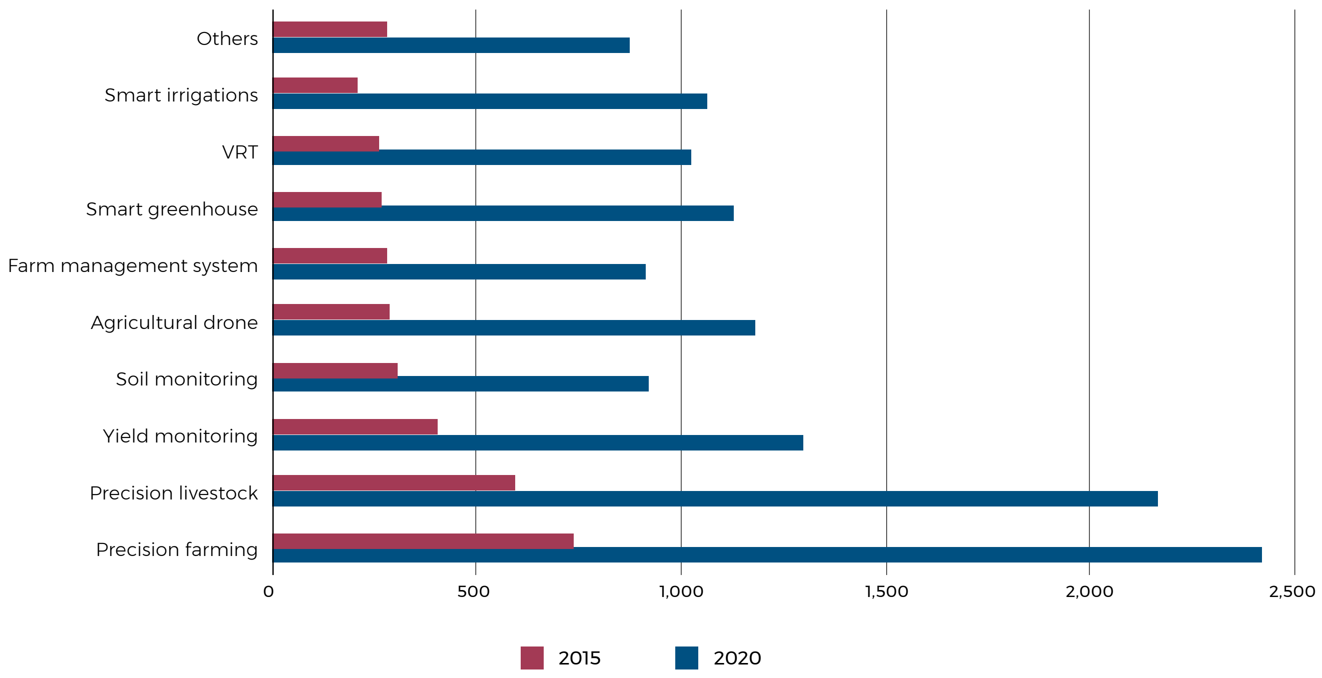


Note: Estimated precision farming market was US$3.06 billion for 2015.

potential for additional value-added services. In the future, mobile operators could provide end-to-end IoT services to generate revenue growth. By 2020, the total addressable market for telecom operators in agriculture is expected to be as large as US$12.9 billion from vertical integration, partnership and marketing, and value-added service perspectives (Huawei, 2015).

For those in LDCs and developing countries that cannot leapfrog from ICT into more advanced technologies, mobile apps addressing various agriculture services must be the primary tools in the short term. As described in Section 3.1.4.1, Africa, Asia and the Pacific region, and the EU have the largest total addressable market compared with Latin America and the Caribbean and North America. Developing regions have much untapped market in which agriculture is largely unorganized. The key factors for successful adaption to these markets include development of local content, testing solutions and training, and favourable regulatory environment. Consolidating these elements will help ensure that the content and methods of delivery are tailored to both markets and crop types, optimizing the potential value for smallholder farmers.

Figure 3-35 Total addressable market size by mobile application 2015-2020, in US$ millions
Source: Huawei, 2015.



3.3.3 DIGITAL INNOVATION ECOSYSTEM

Successful innovation systems are typically characterized by an active knowledge economy, comprising academic, public sector and business R&D and innovation activities with effective commercialization, and all supported by flexible public policy mechanisms. Additionally, successful innovation ecosystems also need a culture of innovation based on interaction, and openness to international opportunities and change (Metcalfe and Ramlogan, 2008). An effective innovation ecosystem therefore enables entrepreneurs, companies, universities, research organizations, investors and government agencies to interact effectively to maximize the economic impact and potential of their research and innovation. The future of food and agriculture will depend on the capacity of agricultural innovation systems to provide farmers with innovations that address an increasingly diverse and complex range of needs, including improved farm productivity and environmental performance, as well as better responses to climate change.

For digital technology, speed and agility are key competitive attributes. Techniques, including rapid prototyping and iteration, have greatly accelerated development and often improved quality. Yet with the nascent technologies that are emerging now, that is often not the case.[80] As stated previously, the key to sustainable agricultural growth is more efficient use of land, labour and other inputs through technology, innovation and new sustainable business models. For the agriculture sector to respond to future challenges, innovation will not only need to improve the efficiency with which inputs are turned into outputs, but also conserve scarce natural resources and reduce waste (Troell *et al.*, 2014). Digital agriculture innovation harnesses the power of digital technologies to pilot, accelerate and scale innovative ideas with high potential for impact in food and agriculture, transforming digital solutions and services into global public goods. It aims to explore the responsible application and adoption of existing and frontier technologies, design and scale new services, tools and approaches to empower rural households, and inspire youth entrepreneurship in food and agriculture.[81]

3.3.3.1 Digital talent development

As digital transformation disrupts the workplace, one factor more than any other will determine which companies turn digital to their advantage. That critical factor is people: the talented employees who can use existing digital technologies and adapt to evolving methods and new approaches. Without these employees, companies will struggle to benefit from the latest advances, everything from Industry 4.0 and robots to AI, data science, VR, and new digital business models. Digitally talented people are already so highly in demand that many large, traditional companies must reinvent themselves to attract them. As digitalization continues to disrupt business, all sectors of the economy feel pressure to hire talent with digital skills, not just sectors once viewed as sitting on the leading technological edge. Those skills are in demand across companies, sectors and industries, including the agrifood industry. The agricultural field has also found it difficult to compete with other tech-savvy industries in attracting young digital talent.

Just as with Industry 4.0, in the digital age, the agriculture and food sector is not spared from this trend. Nowadays, millennials involved in this sector are driving the adoption of telematics and new technology to drive the productivity of their farms. While air-conditioned tractors and automated irrigation systems are nothing new, millennials are significantly involving automation in farming activities. Millennials are coming to agriculture with specific university degrees and specializations. It is about science and technology. It is a new generation that is comfortable with innovation and that loves to experiment. However, to meet their demands, both the public and private sectors must act and enable environment and sustainable digital ecosystem for retaining and generating digital talent for the agriculture and food sector.

3.3.3.2 Innovation sprint programmes

There is huge inefficiency today in both the analogue nature of most of the farming industry as well as the newer digital agriculture sector. As new digital tools replace those old analogues, and the platform approach optimizes the digital sector, there will be a compounding effect on the pace of innovation, making it faster than ever before (Young, 2018). In 2017, the World Economic Forum developed a set of scenarios for the future of global food systems, outlining four distinct possible futures shaped by changes in consumer demand and market connectivity. This work identified technological innovations as one of the elements that will help to shape global food systems.[82]

Governments are seeking to harness digital technologies and entrepreneurship to transform their societies and job markets. Such an ambitious goal, however, requires engagement with local software developers, accountants, engineers, students, entrepreneurs and other experts. Seeing youth as a resource and relying on them for local knowledge allows for home-grown experimentation and gives youth agripreneurs a stake in public policy. In a sector as complicated as digital agriculture, supporting youth agripreneurs through mentoring and providing access to financing is of particular importance.

At first, public interventions should target the creation of start-ups, and later on help these companies grow,

Figure 3-36 Ease of finding skilled employees (rank, 1-7 best), 2018.
Source: WEF, 2018.

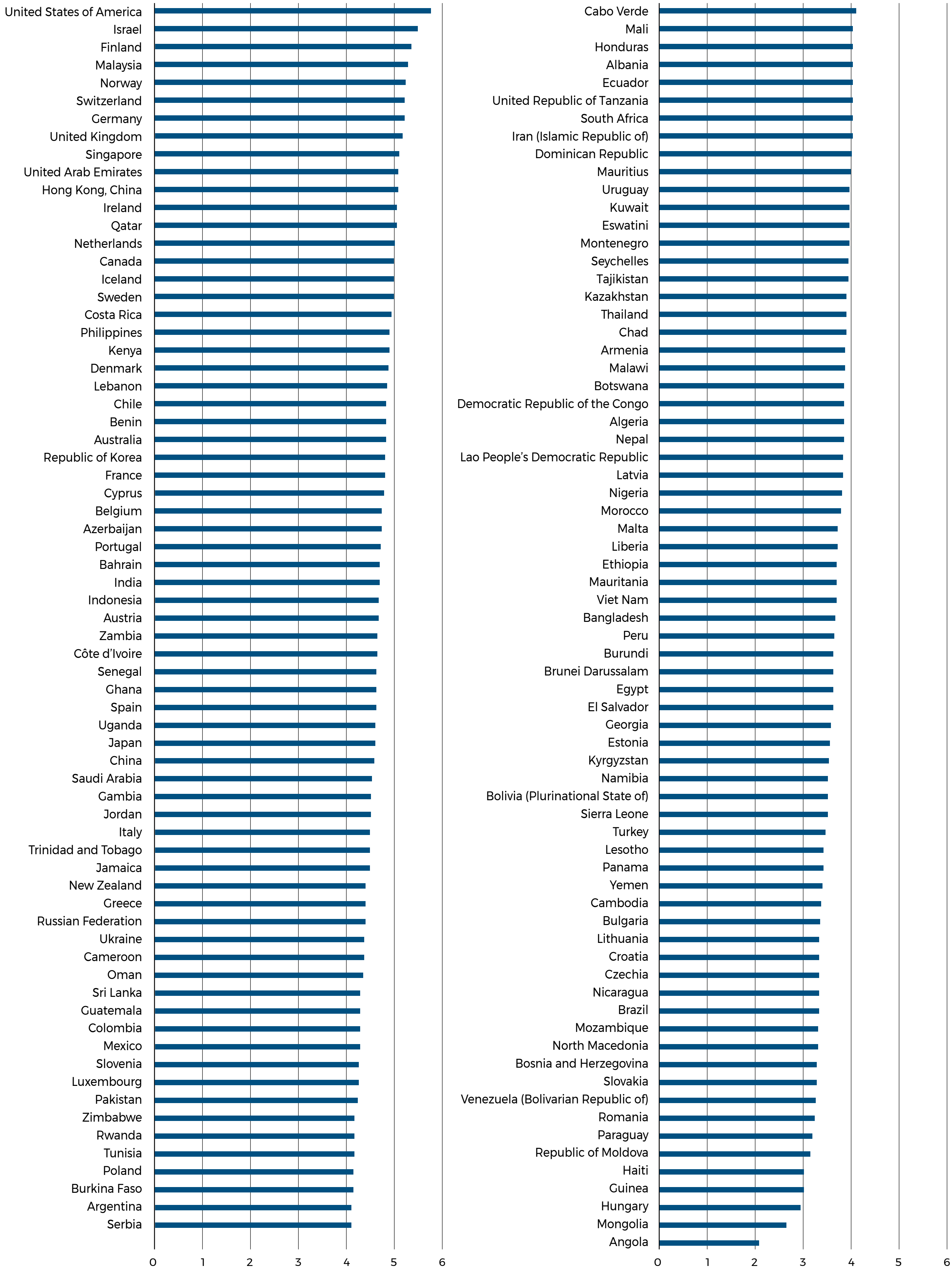
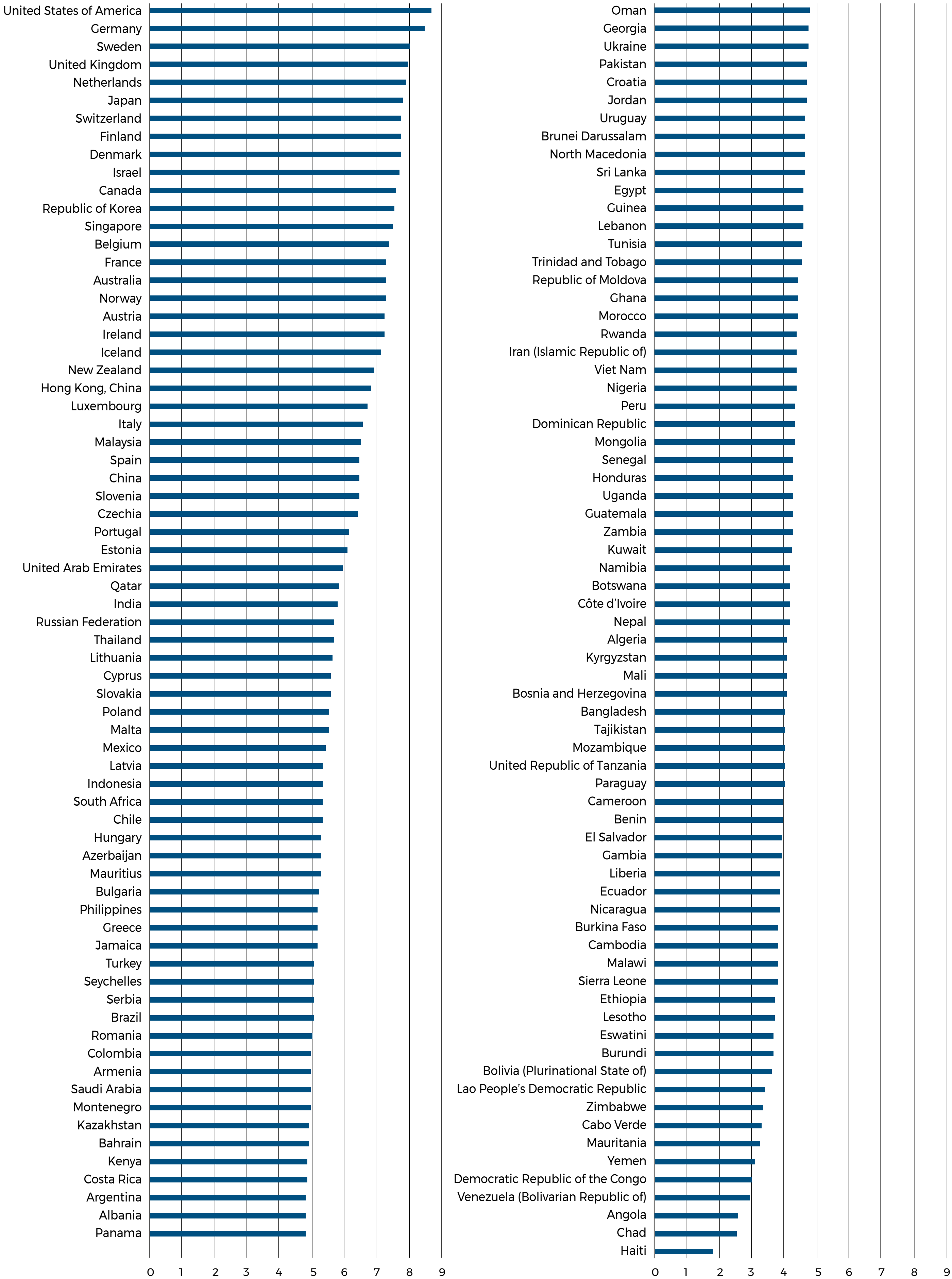


Figure 3-37 Innovation ecosystem (score, 0-100 best), 2018.
Source: WEF, 2018.



scale up and contribute to the development of their regions. The European Commission is supporting innovation ecosystems through Startup Europe,[83] which is connecting start-ups, investors, accelerators, entrepreneurs, corporate networks, universities and the media, as well as linking local start-up ecosystems around Europe.

As of 2017, 830 000 companies are active across 20 key European start-up hubs, employing altogether over 4.5 million people and generating over 420 billion€ in revenue (European Commission, 2017a). Jobs created by the ecosystem bring economic benefits to the local economy that will continue as start-ups evolve and grow.

In Africa, although 50 percent of the tech hubs are concentrated in five countries (South Africa, Kenya, Nigeria, Egypt and Morocco), in almost every other African country there is at least one or two active tech hubs. Moreover, when it comes to tech hubs, some countries were identified as leading countries by sub-region: Morocco, Tunisia and Egypt in North Africa; Nigeria, Ghana and Senegal in West Africa; Kenya and Uganda in East Africa; and South Africa in southern Africa.[84]

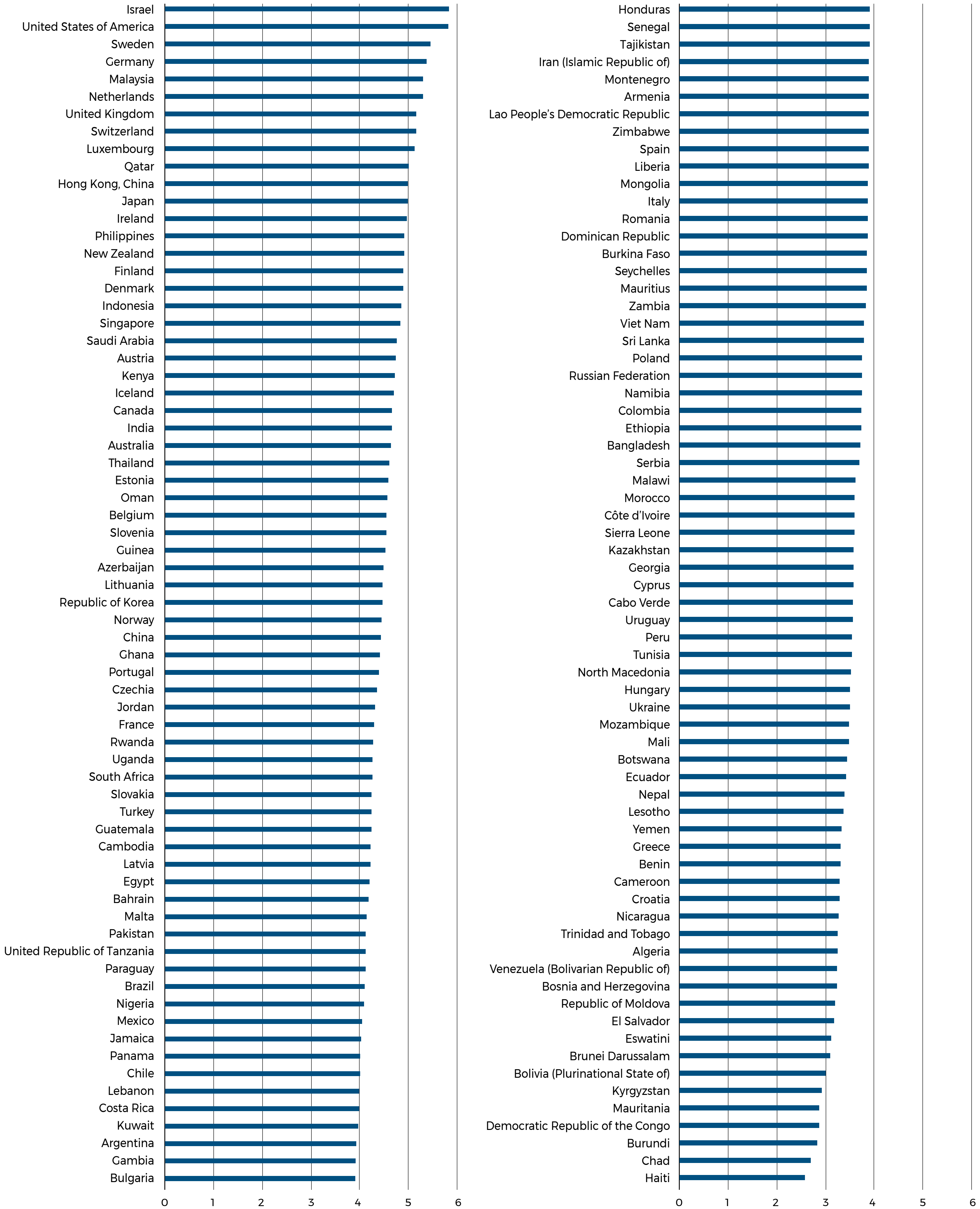
A similar analysis in South and Southeast Asia shows that four countries outside of India (Indonesia, Pakistan, Viet Nam and Thailand) are home to more than 50 percent of the tech hubs in the region. Some smaller markets also have several fairly active tech hubs; for instance, in Myanmar there are seven active tech hubs. There are numerous examples of such activities, including Hong Kong's Cyberport digital hub, the government-backed venture capital fund Infocomm Investments from Singapore, and MaGIC, the Malaysian Global Innovation and Creativity Centre.

Africa and South and Southeast Asia exhibit some differences in terms of tech hub types and concentration. Whereas in most South and Southeast Asian countries there are existing open source listings of the different stakeholders (start-up events, tech media, co-working spaces, incubators, venture capital funds), these are very difficult to find in African countries.

However, aside from the scarcity of support, the main problem for African entrepreneurs is scarce funding: 87 percent of project backers consider this to be very difficult to obtain. The collateral required, along with the high interest rates charged by African banks are often too great to overcome. Alternative sources of finance such as crowdfunding, business angels, venture capital or seed funding remain very limited in their scope and concern very few projects. Private equity in Africa is often focused on growth capital, mostly for well-established SMEs, and

Figure 3-38 Growth of innovative companies (rate, 1-7 best), 2018.

Source: WEF, 2018.



specialized seed or venture capital funds are virtually non-existent outside of South Africa.[85]

“Sprint programmes” are now commonly used for maturing local start-ups in the public and private sectors. For example, a cluster of tech incubators in India are also supporting agriculture innovation, especially in the rural areas. For example, Indigram Labs,[86] a technology-driven business incubator aims to incubate 100 agritech entrepreneurs over the next five years. Sprint programmes are not only organized at country level, but also there are regional-level sprint programmes, such as “Incubator for Digital Farming”[87] among countries in Southeast Europe. Namely in Albania, Kosovo (UNSCR 1244/99) and North Macedonia, youth students and start-ups are gaining demand-driven and innovative agriculture education, training and skills development programmes geared towards digital transformation and maturing their products and services.

This trend in talent development is also present at global and continental levels, and UN agencies also take part. In 2018, FAO launched four youth innovation regional challenge competitions to find high-potential digital solutions to address challenges in food and agriculture and to improve livelihoods of smallholder farmers and rural households. Examples are seen in the Caribbean region, in a partnership with local universities in Jamaica and Trinidad and Tobago; in Rwanda, which hosted 24 youth participants in eight teams across seven countries in Africa in partnership with Rwanda ICT Chamber;[88] and in Geneva, with 73 entrepreneurs, 14 teams across four continents, in partnership with ITU and Geneva Impact Hub.[89] Pitch-AgriHack Initiative[90] is another sprint programme organized by CTA and various partners, including FAO and WBG, on an annual basis. This sprint programme hosts plenty of start-ups across Africa and the goal is to match them with potential partners, such as the African Development Bank, the Alliance for a Green Revolution in Africa, telecom companies, private investors, etc. Up to 2018, about 700 young entrepreneurs have taken part in Pitch-AgriHack and around 26 ICT hubs or institutions from 20 countries have been involved. Since the launch of the initiative, at least 500 000 farmers and agricultural stakeholders have received services provided by applications developed by these start-ups. Also, start-ups involved have raised more than 2 million € from investors and partners. For example, Agripredict,[91] a Web and mobile-phone agricultural risk management platform, built on artificial intelligence and machine learning, is serving more than 22 000 farmers in Zambia. In Ghana, the online farmer’s market and grocery store Farmart Limited[92] is a platform for fresh farm produce and groceries. CropGuard[93] is a free mobile app for farmers and householders from Barbados and provides information on crop protection against pests.

Digital agriculture innovation is both knowledge- and skills-intensive because agricultural production systems are complex and multifaceted and solutions require knowledge ranging from broad to specific (van Es and Woodard, 2017). Driving digital agriculture innovation means starting from ideation to implementation, testing and scaling new technology solutions and generating opportunities to promote entrepreneurship and new business models. When it is properly supported, digital innovation can act as a powerful catalyst for achieving SDGs.

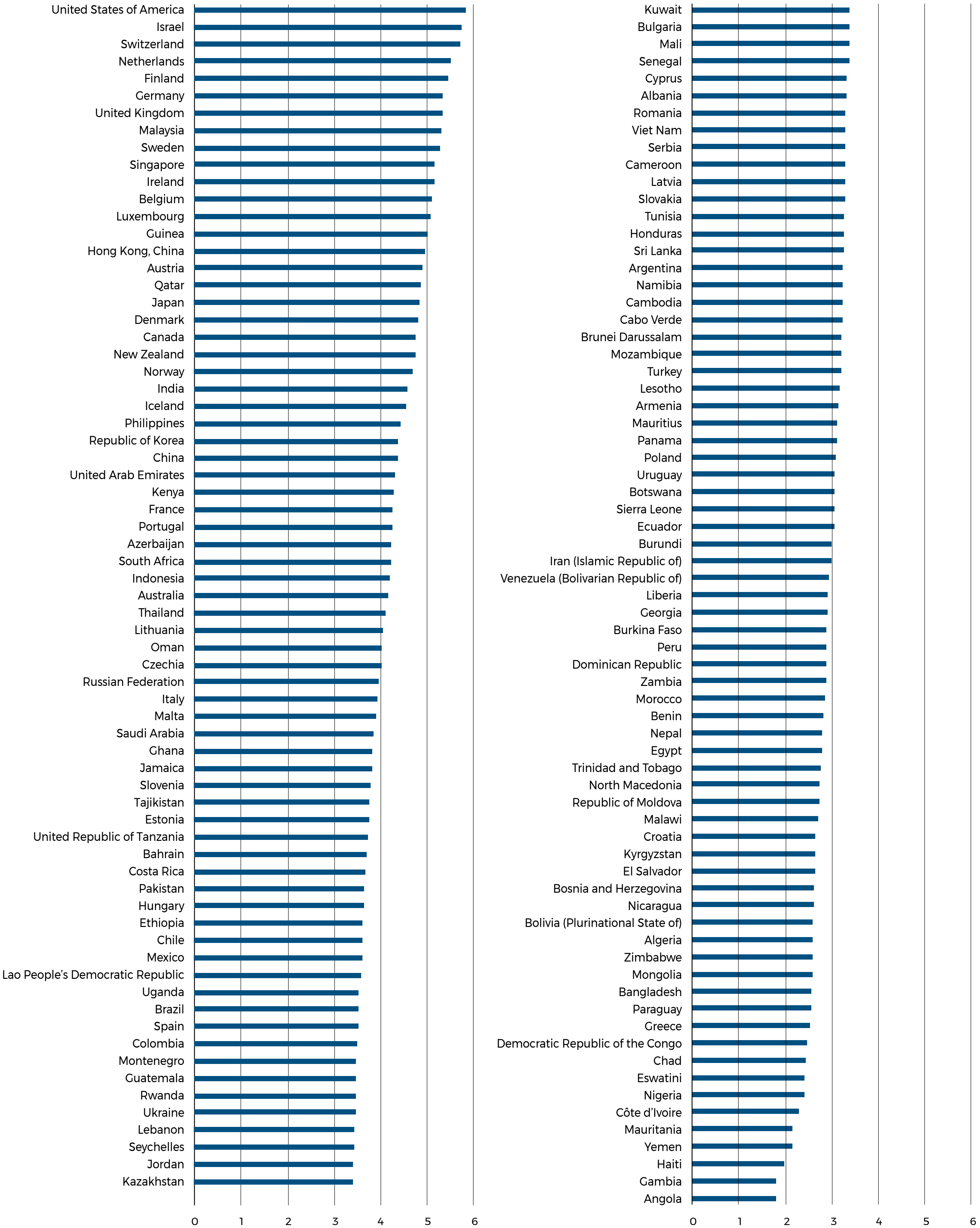
3.3.3.3 Innovation cooperation and R&D

At the industry level, we have witnessed consolidation across the largest players. Dow/DuPont, ChemChina/Syngenta and Bayer/Monsanto have all merged, or are in the process of merging. One of the main drivers behind this consolidation is increased efficiency in research and development. Today, these companies invest the same dollars in their R&D infrastructure, but the pace of innovation is slow, as companies often must wait until products are commercially available before beginning development of complementary innovations. The opportunity created with these mergers is that even with maintaining existing R&D investment levels, the mergers will bring more innovations to market more cost effectively and at a much faster pace, as these allow elimination of redundancy, combined with simultaneous development across R&D lines (Young, 2018).

Digital technologies are bridging vast distances and converting the world into a global village, bringing global companies closer to local economies. The private sector and universities are the natural homes to facilitate collaboration between business leaders and businesses that could be digitally transformed, as they bring together local resources and facilitate collaboration between local stakeholders (industry, policy-makers and academia, etc.). These collaborations have produced many of the smartest digital initiatives, including those related to digital agriculture, thus greatly increasing the attractiveness of participation (European Commission, 2017b). Facilitating knowledge access by sharing research results and improving knowledge transfer between research institutions and industry is key for creation of innovation ecosystems.

The ability to connect with external experts, lecturers, schools and universities (both nationally and internationally) could increase the number of courses offered in the curricula and attract more students. For example, the BioSense Institute[94] in Serbia is matching science and technology. The main focus of this institute is multidisciplinary, game-changing and needs-driven research and to disseminate it to a global ecosystem of forward-looking stakeholders. Other institutes and

Figure 3-39 University-industry collaboration in R&D (rate, 1-7 best), 2018.
Source: World Economic Forum, 2019.



universities, such MIT and Cornell in the United States, Wageningen in the Netherlands or Tsinghua in China are pioneering this approach.

For both students and teachers, ubiquitous connectivity facilitates greater collaboration and innovation, thus enabling youth digital agripreneurs to develop increasingly connected rural communities in the agriculture and food sector. Being more available to students can also empower teachers to deliver more innovative, exciting lectures, whether face-to-face or online, while offering more personalized feedback and mentoring.[95]

However, students in developed countries have not seen agriculture and food as an attractive sector. For millennials, industries such as IT, commerce, manufacturing, etc., are the priority. Currently, most researchers in the agriculture sector are in developing countries. These are the countries where the agriculture sector is predominant and most of the population lives in rural areas, mostly in East Africa and the majority of Latin America.

However, in the era of digitalization, when more and more digital technologies are becoming available in the agricultural sector, interest in agriculture is being revived for students in developed countries. In the United Kingdom, for example, agriculture was the fastest-growing subject at the university level in 2015, with a 4.6 percent increase in student numbers, and more than 19 000 agriculture students. But, according to the agency Agricultural Appointments, Australia needs 20 percent more agriculture-related degree holders to satisfy the job market and to secure the country's farming.[96] Between 2015 and 2020, the annual demand for college graduates in the agriculture and food industries accounted for around 58 000 jobs in the United States. The gap between job opportunities and the number of agricultural graduates is large: American agricultural colleges only produce about 35 000 graduates per year. In general, at a global level, more students are needed to meet the demand for agricultural professionals, especially those possessing digital skills and knowledge of digital agriculture.

To attract more students and make agricultural R&D competitive and foster digital innovations, support is needed from both the public and private sectors; however, it is noted that more universities are public and dependent on government support. Hence, the public sector continues to be the main source of funding for agriculture R&D, whether performed in public or private organizations. A wide variety of funding mechanisms are used; from direct spending on research projects, including public–private partnerships (PPPs) and "pull mechanisms", to various forms of tax incentives. Business investment in R&D is normally driven by market demand, but governments also provide a variety of incentives. Some, like R&D tax rebates, apply to the economy in general, whereas others are agriculture-specific. In many countries, producer organizations and other nongovernmental organizations also provide R&D funding (OECD, 2015b).

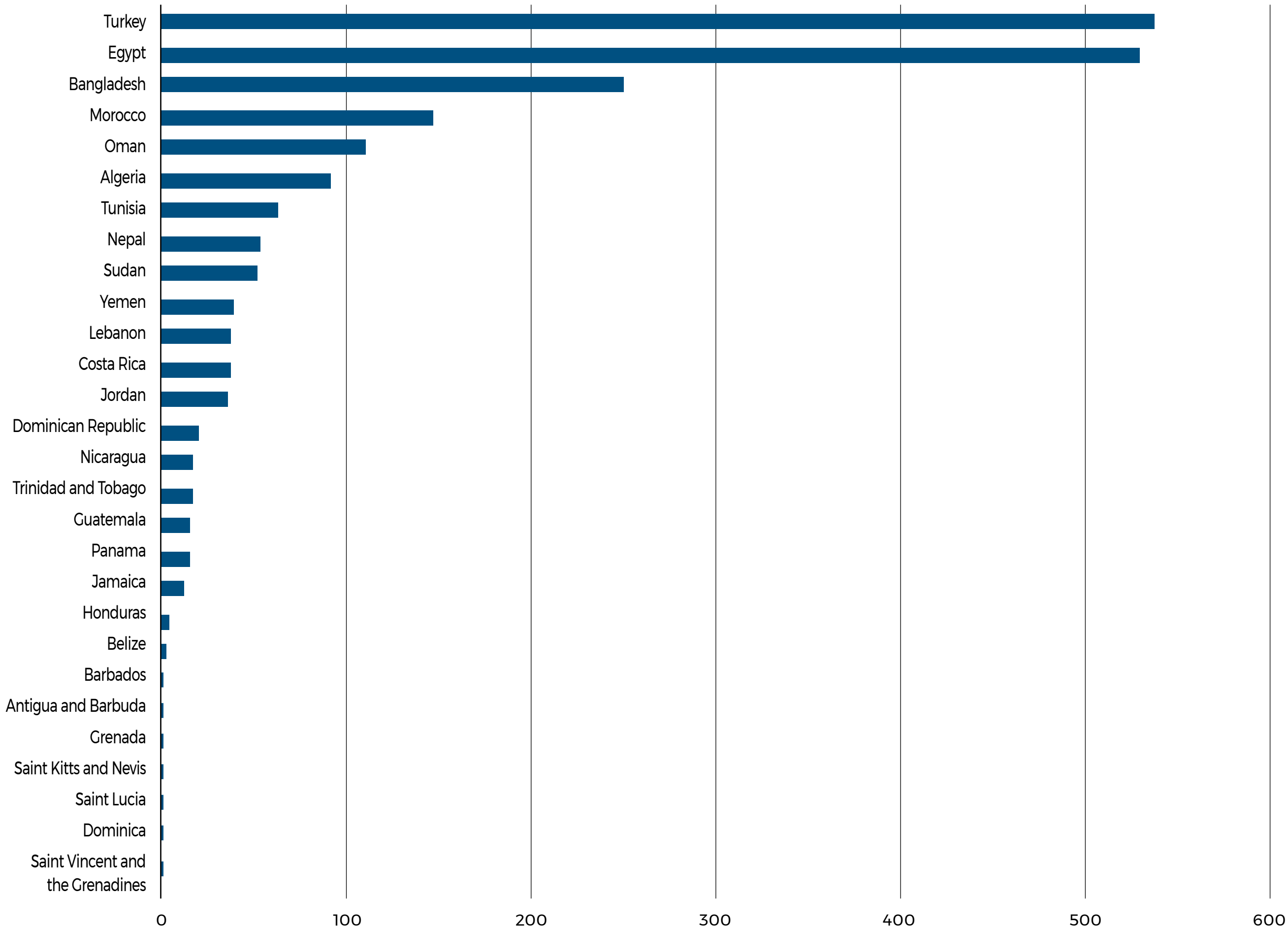
In February 2019, FAO published an article on agriculture expenditure. From 2001 onwards, governments allocated less than 2 percent of their central government expenditure to agriculture. Asia and the Pacific region allocated the highest percentage of central government spending to agriculture between 2001 (3.85 percent) and 2017 (3.03 percent). This was followed by Africa, where the share has progressively declined from 3.66 percent (2001) to 2.30 percent (2017). The developed regions (Europe and other developed, which refers to Australia, Canada, New Zealand and the United States) allocated the lowest share of central government expenditure to agriculture, both series fluctuating around 1 percent.

3.3.4 CONCLUSION

When rural development is government's priority, we will witness the emergence of new approaches to encouraging investment, which will strengthen the links between smaller communities and larger centres and will attract and grow businesses in rural communities. Youth engaged in agrifood sector have become more entrepreneurship-oriented and have learned to take calculated risks to open enterprises. Also, the number of small-scale farmers having many of the qualities of an entrepreneur is increasing. Digitization of the agrifood value chain is already under way. Venture capitalists expect this to trigger a big shift in how food is produced and brought to the table. And, although this is also beginning to happen in Europe and Asia, Africa will be a major testing ground for these agritech groups, with its large farming base and consumer market.

Despite the rapid growth of digital agriculture businesses and applications, most ICT-enabled solutions have yet to reach scale and companies are struggling to move from start-ups, or even from application owner, to fully fledged businesses. Within ICT there are a few successful examples of technically advanced solutions that radically change opportunities in underserved markets. However, there is a lack of similar successful examples by SMEs or start-ups. Many companies manage a promising pilot, but find execution of a scale-up to be very complex. The reasons are still not well researched and current literature for scaling strategies in underserved markets is simply not sufficiently preparing or guiding entrepreneurs.

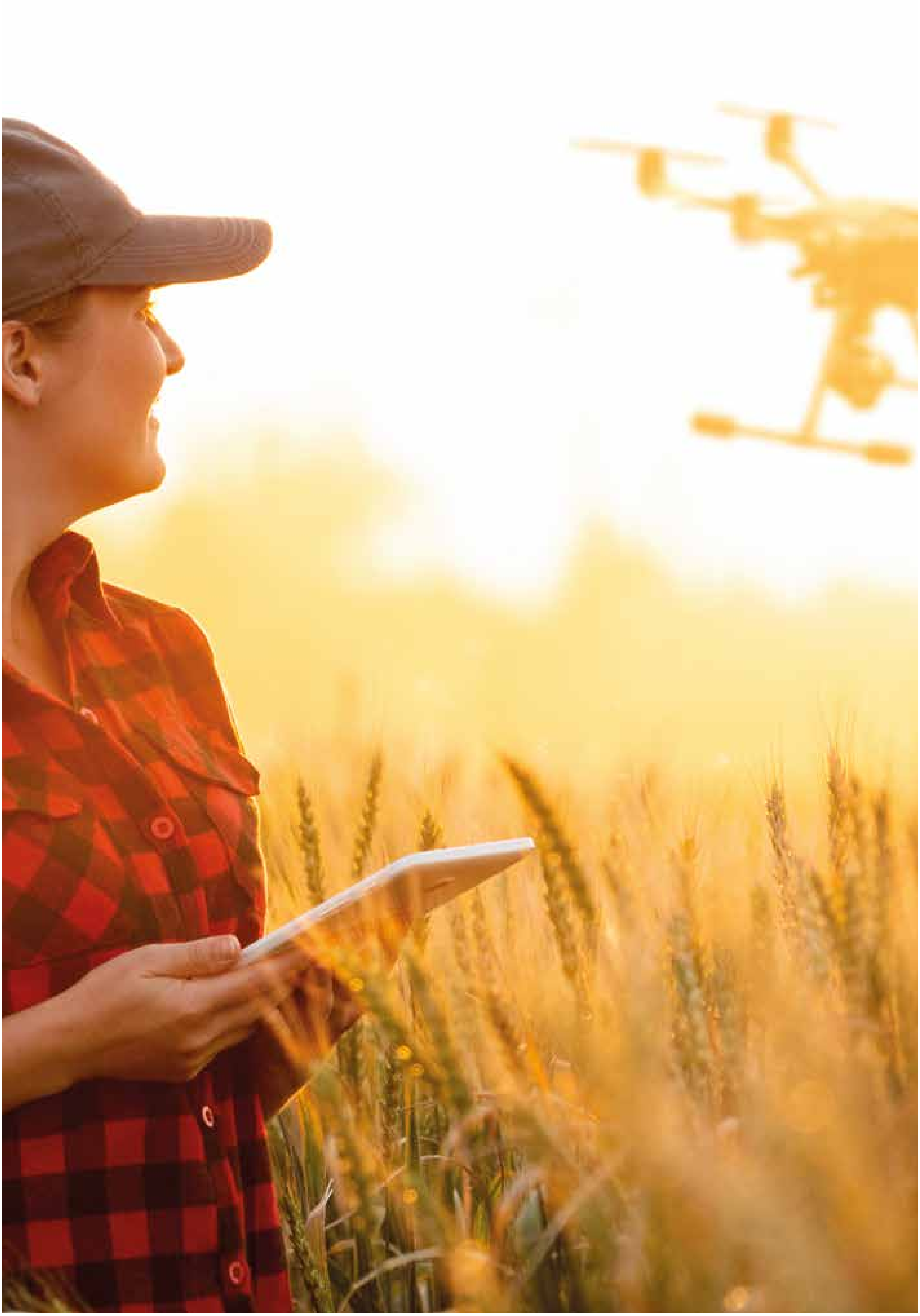
Figure 3-40 Agriculture research spending in 2012, 2011 PPP$.
Source: FAOSTAT, 2018.



Companies should respond to this challenge by building new pools of skilled digital employees. To do so, they must understand who these potential employees are, where they can be found, and how they can be attracted and retained. Companies also need to know what kinds of talent can be nurtured within the existing employee base; digital talent must come not only from the acquisition of new personnel for specific jobs but also from the development of digital skills in existing roles.

Recognizing that education is the most critical factor to accelerating innovation, digital and socio-economic transformation, we recommend that governments urgently adopt a three-pronged approach to stimulating R&D and innovation education across the continent: investing in R&D, amplifying indigenous R&D and co-creating education systems and curriculum redesign together with a broad coalition of partners, such as labs and civic spaces, emphasizing e-learning tools and do-it-yourself, hands-on learning, rewarding experimentation, failure and critical thinking, and teaching digital and financial literacy and software skills.

Finally, the youth digital agripreneurs bring together solutions that come from years of observing missed opportunities and listening to what farming communities want. In many cases, these start-ups are from the smallholder farming communities that seek to help, draw inspiration and drive from parents and grandparents back at home. The agricultural sector has not yet fully integrated digital technology, but we are already starting to see the impact of innovative digital solutions, and the results are becoming catalytic. The rise of youth digital agripreneurs is on the horizon. There is a huge opportunity in digital agriculture for young people with an entrepreneurial spirit, particularly for those entrepreneurs who are not yet active in the field of agriculture and food. It is about time young agripreneurs start to show their potential added value to digital innovation start-ups. They need sprint programmes and financial support to penetrate the market, because the trends in investment are correlated with trends in incubating programmes, initiatives and support from government and academia.



4 IMPACT OF DIGITAL TECHNOLOGIES ON THE AGRIFOOD SYSTEM – CASE STUDY EVIDENCE

Incorporation of digital technologies in agriculture, whether at the level of access to information, transactional services or advisory or integrated solutions, partially or in all the value chain, generates impacts that should have implications in the economic, social/cultural and environmental areas. However, the relationship between the incorporation of technology and a positive impact is not direct, because to generate these positive impacts it is necessary not only to implement technology, but also other elements, as they have been previously analysed in relation to basic conditions and enablers, so that technologies are incorporated into economic, social and culture processes. Therefore, one of the greatest risks that exists in the digitization process, in particular in the agriculture and food sector, is to believe that by the mere fact of implementing or making available a technology, the expected results will be achieved. One of the phenomena observed in relation to incorporation and adoption of technology corresponds to the "Law of Disruption" (Downes, 2009), which states that technology changes exponentially, but economic and social systems change progressively and have trouble keeping up.

In many areas where a new digital technology will be incorporated, users will benefit from its adoption, depending on the availability of complementary goods and/or services, provided they have the appropriate minimum conditions, such as those described in the previous sections (basic and enabling conditions), while the benefit to those who promote this technology (investor and entrepreneurs) depends on the possibility to offer complementary goods and/or services, based on the installed base of the primary goods/services. The interdependence between the demand for the primary good/services and the supply of the complementary goods/services is referred to as an indirect network effect (Varian, Farrell and Shapiro, 2004). Therefore, understanding the nature of this equilibrium is crucial for identifying the diffusion path of the new technology and for designing effective policies to promote the technology in a positive digital transformation process. Although it is possible to analyse case by case the existing technologies in the area of agriculture and food, this will only imply a stocktaking exercise, which undoubtedly is necessary, but unfortunately is not sufficient. For this reason, a broader, inclusive and integrated vision is required that accounts for how the different factors are articulated and related to form a virtuous circle around the adoption and digital transformation.

Identifying potential opportunities for increasing social, economic and environmental growth, measuring its impact and, at the same time, allowing small-scale farmers and agripreneurs to create new values, will move the agrifood system to the next stage of digital maturity. While the benefits of digital agriculture are still not proven, it has met with significant challenges, for example, difficulty using software, data usage concerns, disparate and propriety data formats, and an unclear return on investment. The gap between modern, advanced farming and subsistence farming is growing at an alarming rate. Despite the cost of implementing digital farming technology in the developed world having fallen substantially, the weak network infrastructure and limited capital of emerging economies means they are still a long way from benefitting from the digital agriculture revolution.[97] According to Pesce *et al.* (2019), some new technologies, such as IoT, Big Data and AI, are contributing to traceability by integrating information of different segments throughout the whole value chain, and by means of effective use of inputs that fit customer needs. Other uses of the same technologies include reduction of environmental and climate risks in production systems, in which customers suffer fewer negative impacts.

The food-value chain (FVC) comprises the value chain actors who produce or procure products from the upstream level, add value to these products and then sell them on to the next level. These actors carry out four functions: production (farming, fishing, forest harvesting or agroforestry), aggregation, processing and distribution (wholesale and retail). New digital technologies are driving profound changes across different aspects in the agrifood value chain, especially in developed countries, to increase productivity, food security and transparency. To realize a more sustainable, secure, inclusive, agile, climate-smart agrifood value chain, there is a need to identify where and how these new technologies are been used and creating value (FAO, 2014).

This section presents a review of the different types of digital technologies used in the area of agriculture and food through the value chain. This exercise does not pretend to be exhaustive, but in a descriptive way it attempts to identify how these technologies aid economic, social/cultural and environmental improvement where they have been implemented. Towards the end of this section an analysis of particular cases is attempted where beyond the description of the technology, factors that have facilitated a successful result are identified.

4.1 Production

Production is the first stage of the FVC and consists of the transformation (input, processes and output) generated by agricultural products by different type of actors. These actors are linked to each other and to their wider operating environment through a governance structure. There are horizontal linkages among the actors at a particular stage of the chain, for example farmers organizing themselves into cooperatives; and vertical linkages within the overall chain, for example farmers providing their produce to food companies through contracts (FAO, 2014).

4.1.1 MOBILE DEVICES AND SOCIAL MEDIA

Mobility has rapidly become the world's most used technique of transmitting data, voice and various sorts of services. Section 3.1.4.1 "Mobile apps for agriculture" presents an analysis of the stocktaking exercise, identifying and characterizing how this technology has been developed in the agriculture area.

Today, there are tens of thousands of applications available in the area of agriculture. Most of the applications are oriented to specific aspects, but some others are based on platforms (ecosystem), where there are many interconnected applications (Qiang *et al.*, 2012). These applications provide information (SMS or more advanced), deliver transactional services and provide advisory services for decision-making help. However, mobile devices and applications are more popular in those areas with little connectivity and used more by small farmers. According to Qiang *et al.* (2012), the benefits of these apps in the development of the agricultural sector can be achieved through the following ways:

- Provision of better access to information: providing producers immediate access to market information can allow them to attain higher product prices. Also, by accessing accurate information regarding weather and pest and diseases, better risk management is achieved.
- Provision of better access to agricultural extension services: accurate advice can be given for good farming practices and support. This could result in crop yield improvements and more accurate assessments of the condition of pastures.
- Provision of better connections with the market and distribution networks: with the improvement of links among producers, suppliers and buyers, value chains become more transparent and efficient, less manipulated by intermediaries. In addition, better accounting and traceability helps to increase efficiency and forecasting and to reduce administrative burden and fraud.
- Provision of better access to funding opportunities: with access to funding and insurance opportunities and alternative payment methods, farmers can achieve an increase in crop yields production diversification and reduction of economic loss.

In an important review of mobile apps in terms of results of Web of Science search for citations dated Jan 2008–Nov 2017 and Web site or developer links for apps noted in text, over 6100 citations were returned for "smartphone application" (Eichler Inwood and Dale, 2019). This is a test of the amount of activity and variety of applications in this field. The apps can be found independently, where most of the projects correspond to projects and tests and can generate valuable solutions in the market.

Likewise, these apps can be found on platforms, where they are integrated with other types of services, and where, in general, they correspond to commercial and/or governmental solutions.

A growing body of evidence suggests that in many circumstances, information and digital technologies, specifically mobile phones, can help address economic, social and environmental problems in rural areas. Although connecting farmers and buyers is a great start, continuous support is needed to solve the logistical delivery of produce, particularly from farmers in remote rural areas.

In terms of economic impact, there is evidence that use of mobile applications with price information can help to reduce price market distortions, and increase production and income. In the cocoa and coffee market, a unit increase in mobile phone usage will reduce price distortion by 0.22 percentage points on average (Nsabimana and Amuakwa-Mensah, 2018). The total effect of mobile phone usage on price distortion is highest in Mexico with a rate of about – 0.54 percentage points, followed by Brazil with a rate of about – 0.32 percentage points. Ethiopia and Madagascar were found to have the least effect of about – 0.14 percentage points and – 0.15 percentage points, respectively.

In this same area, studies have identified the impact of price dissemination (Torero, 2013) through radio. For example, access to market information resulted in higher farm-gate prices (around 15 percent) for maize in Uganda (Muto and Yamano, 2009). Similarly, large effects have been suggested in Peru and the Philippines (Futch and McIntosh, 2009), but there are also cases in which no or much smaller effects were found (Muto and Yamano, 2009). In the case of M-Farm in Kenya, Baumüller (2015) found that price information can help farmers plan production processes better when deciding what to grow and when to harvest. Many farmers changed their cropping patterns, although they mainly expanded existing rather than grew new crops. There were reports that M-Farm had helped the farmers obtain higher prices and raise their income, but the evidence from the study is inconclusive. In India, there is evidence that use of mobile phones encouraged poor farmers towards greater market participation and diversification to high-value crops (Mittal and Mehar, 2012). This change has helped increase farm earnings through higher price realization, reduction in wastage and increase in income. Another example is mKrishi,[98] which increased farmer profitability by 45 percent in India, by providing access to information to help farmers improve yield and connect with supply chains.

The resilience of agricultural livelihoods is key to making sustainable development a reality by ensuring that agriculture and food systems are productive and risk sensitive to feed present and future generations. In general, under this area we have climate-smart agriculture, an approach to agriculture that sustainably increases productivity, enhances adaptation and mitigates emissions where possible. In this area, there are some specific cases of mobile applications, where we can highlight the following.

a) Helping farmers in terms of crop growth and occurrences of pest attacks or crop failure, climate-smart adaptation. In most of these cases a mix between mobile devices and AI algorithms have been developed. Although there is no revision of the mobile applications (market and projects), we present a couple of cases. FAO has implemented the Fall Armyworm Monitoring and Early Warning System (FAMEWS) to monitor, analyse and produce early warnings, including risk to food security, including recommendations on pesticide management, monitoring and early warning, and a practical guide for farmers and government extension workers on how to best manage the pest.[99] Also, Plantix,[100] developed by German start-up Progressive Environmental and Agricultural Technologies (PEAT), uses deep learning to detect more than 300 diseases, from images of crops uploaded by farmers. Besides diagnosis, the automatic image recognition app geo-tags uploaded images to monitor crop health across regions. MyIPM apps[101] provide information on dozens of insects and diseases that infect peaches, blueberries, strawberries, apples, pears, cherries, cranberries and blueberries.

b) Precise and timely weather-based agroadvisory messages help in making informed decisions about input use (Mittal, 2016), thus leading to savings on irrigation and reducing the cost of other inputs such as pesticides and fertilizers. Women farmers also said that agroadvisory messaging helped them make more efficient use of inputs by increasing their knowledge about climate-smart technologies. The weather and crop calendar app (FAO and WMO) combines information on weather forecasts and crop schedules, providing early warning of potential risks. The cure and feed your livestock app helps reduce losses by providing information on animal disease control and animal feeding strategies.

Although it is possible to identify a large number of mobile applications (apps), there is little evidence regarding their use and the impacts that this may imply in relation to agriculture, risks and results. This opens up the possibility of greater standardization, especially as a repository and promotion of this type of solution.

Youth around the world are increasingly turning away from agriculture. Traditionally requiring tough manual labour and offering low wages, agriculture does not often appeal to new generations who generally prefer to try their luck finding jobs in cities.[102] Mobile technology and applications bring opportunities for youth and gender in rural areas.

In a recent study, Sekabira and Qaim (2017) concluded that mobile phone technologies can improve household living standards, gender equality and nutrition in rural areas, especially when women have access to mobile phones. Women seem to benefit over-proportionally from mobile phone technologies, which is plausible given that women are often particularly constrained in their access to markets and information. Hence, a new technology that helps reduce transaction costs and allows new forms of communication can be particularly advantageous for women. Higher incomes and better access to information for women positively influences their bargaining position within the household, thus also improving gender equality and nutrition.

The Kenya Agricultural and Livestock Research Organization (KALRO) launched 14 mobile applications[103] to help farmers transfer technologies that enhanced agricultural productivity and trade in 2018.[104] The mobile apps target crops such as avocado, banana, cassava, maize, guava, cowpea and potato. The platform will "help farmers acquire genuine information unlike the conventional models that are open to farmers receiving wrong information that lead to growing of fake and unrecommended seeds",[105] and this platform also will help "to improve research data democratization and insights to inform policies particularly on improving smallholder farmers' livelihoods".

An estimated one-third of all food produced globally is either lost or wasted. In an age where almost one billion people go hungry, this is unacceptable. Food loss and waste (FLW) represent misuse of the labour, water, energy, land and other natural resources that went into its production.[106] In an EU research project, the REFRESH study (Vogels *et al.*, 2018) indicated that most apps cover the areas of planning and storing of food, in particular on announcing product expiration; followed by apps in the areas of provisioning, preparation and disposal of food; fewer apps are available in the area of consumption of food. Apps and Web sites with shopping list functionality only indirectly reduce food waste but seem to be the most popular applications. However, the

CASE 1 FAO MOBILE APPS AS DIGITAL ADVISORY SERVICES IN RWANDA AND SENEGAL

FAO DIGITAL PORTFOLIO

Agricultural Services Apps

A set of new apps is providing farmers with real-time services through information on weather, livestock care, markets and nutrition. The weather and crop calendar app combines information on weather forecasts and crop schedules, providing early warning of potential risks. The cure and feed your livestock app helps reduce losses by providing information on animal disease control and animal feeding strategies. AgriMarketplace enables farmers to obtain better information about suppliers for raw material purchases, marketplaces to sell their products and market prices. e-Nutrifood gives rural people recommendations on producing, conserving and eating nutritious foods.

The Fall Armyworm Monitoring and Early Warning System (FAMEWS) app aims to tackle a devastating pest destroying maize and other important crops across parts of the Americas, Africa and Asia. Only farmers in their fields can successfully manage Fall Armyworm. That is why FAO has developed a tool to capture data uploaded by farmers in their fields. The information added to the app is transferred to a global Web-based platform and analysed to give real-time situation reports, calculate infestation levels and suggest measures to reduce impact.

Water Productivity through Open access of Remotely sensed derived data (WaPOR) monitors and reports on agriculture water productivity over Africa and the Near East. It provides open access to the water productivity database and its thousands of underlying map layers. It allows for direct data queries, time series analyses, area statistics and data download of key variables associated to water and land productivity assessments. The portal and app services are directly accessible through dedicated FAO WaPOR APIs, which will eventually also be available through the FAO API store. Water productivity assessments and other computation-intensive calculations are powered by Google Earth Engine.

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 systems. 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 on food security and livelihood. EMA-i is currently used in six countries in Africa (Cote d'Ivoire, Ghana, Guinea, Lesotho, United Republic of Tanzania and Zimbabwe).

Collect Earth is a tool that enables data collection through Google Earth. In conjunction with Google Earth, Bing Maps and Google Earth Engine, users can analyse high and very high resolution satellite imagery for a wide variety of purposes, including: (a) support of multiphase National Forest Inventories; (b) Land Use, Land Use Change and Forestry (LULUCF) assessments; (c) monitoring agricultural land and urban areas; (d) validation of existing maps; (e) collection of spatially explicit socio-economic data; and (f) quantifying deforestation, reforestation and desertification. Its user-friendliness and smooth learning curve make it a perfect tool for performing fast, accurate and cost-effective assessments. It is highly customizable for specific data collection needs and methodologies.

Source: www.fao.org

CASE 2 MOBILE FINANCIAL SERVICES AVAILABLE IN DEVELOPING COUNTRIES

M-PESA

Mobile money

M-Pesa was launched in 2007, and is still going strong. The concept of a phone-based money transfer service originated back in 2002, when researchers realized the popularity of the market for phone airtime individuals in a handful of African nations often transferred it to friends and family for subsequent use or resale. Paving the way for the as-yet non-existent M-Pesa, the researchers presented the research to a telecom provider, who became the first to authorize the transfer of airtime.

Vodafone, via its local operator Safaricom, became the project partner and rolled out the service. In 2013, around 16 million people had M-Pesa accounts. Since then it has expanded to Afghanistan, South Africa, India, Romania and Albania; the system processes more payments than Western Union does across its entire global network.

The system is simple in concept; users pay money in to one of 40,000 M-Pesa agents (who usually operate in small corner shops), who sell airtime on the Safaricom network. Withdrawals can be made by visiting another agent and the system can also be used to send money to other people via a simple menu on the phone.

Mobile money of this kind has also been used with increasing effect by aid agencies looking for an alternative to food distribution in humanitarian crisis situations. By setting up a mobile phone network running M-Pesa, it becomes possible to distribute and control flows of cash such that affected people can make purchases themselves rather than depending on aid convoys.

Several aspects of the M-Pesa case are worth drawing out as a study of innovation. First, it is a good demonstration of the social aspects of diffusion of innovation. Kenya, like many African societies, is heavily dependent on personal relationships and word-of-mouth represents a key way for ideas to spread. In the case of M-Pesa this helped build up the network effect; essentially, without a critical mass of people connected to the system it does not offer much advantage. The more connections there are, the more attractive the system becomes. In the case of M-Pesa, this ‘tipping point’ was reached quite early and the widespread connectivity then enabled other services to be added which reinforced the value and drew more subscribers into the network. This network effect extended beyond the phone use itself to the network of retail stores able to offer the service so that people could deposit and receive money.

Source: www.mpesa.in/portal/

limited amount of scientific research that is currently present gives some indications that apps can help in raising consumer awareness regarding food waste, but the effects on food waste behaviour are unknown.

The effectiveness of these tools for advancing sustainability goals is unknown. Apps that connect farmers, extension agents and other agricultural actors to information relevant to the ways in which farm management decisions affect landscape sustainability are still needed. Such apps should be capable of filtering cloud-based information using GPS inputs cross-referenced to GIS resources, generic Internet-of-things sensors, volunteered geographic information, crowd-sourced data, and social networking for broad knowledge exchange and peer-to-peer learning (Eichler Inwood and Dale, 2019).

Mobile applications have many challenges such as lack of mobile-friendly and locally relevant digital content (Torero, 2013), rural mobile infrastructure limitations (connectivity, network and signal, electricity problems), and affordability related with the benefits, e-literacy, large number of local languages. Because most of the apps are related to projects and research, they do not scale properly, making their adoption and location difficult in a sustainable way. This problem should be solved when the most attractive apps in the market are integrated into platforms, forming part of a broad service to farmers.

4.1.2 PRECISION AGRICULTURE AND IOT TECHNOLOGIES

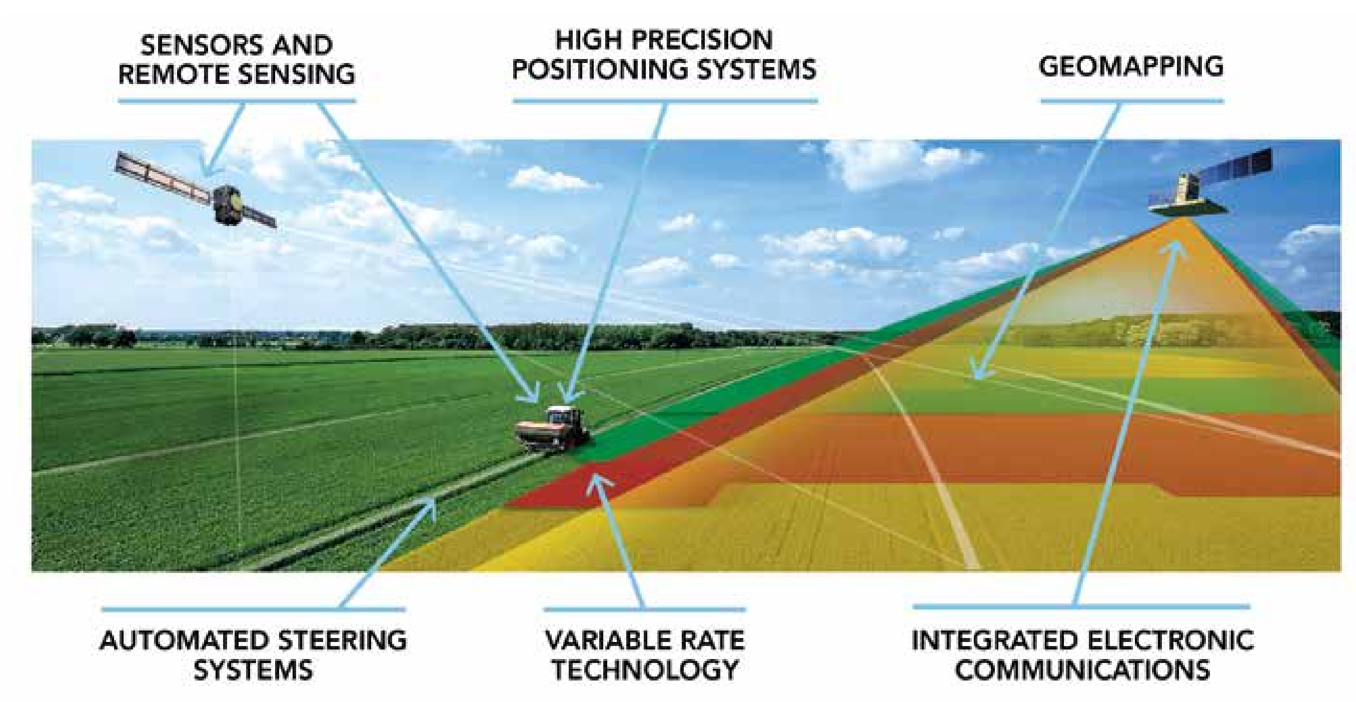
Precision agriculture (PA) is one of the most well-known applications of IoT in the agricultural sector and numerous organizations are leveraging this technique around the world. PA employs technologies like GNSS, VRT and drones that are connected through remote sensors to measure spatial variability, communicate farm conditions, plan irrigation and harvesting, and thus eliminate human intervention to a large extent. In IoT-based PA, data from the sensors can be shared with the stakeholders either through a local server or the cloud, depending on the reliability of the communication network and Internet connectivity. These data are accessed via smartphones, and user-friendly apps can be used to represent the data in a simple and clear format.

In PA, the fields are treated applying variable rates of inputs (irrigation water, fertilizers, pesticides, etc.) according to the actual needs of each location in the field. In this way the efficiency is increased, and yield, quality and impact on the environment are optimized.

4.1.2.1 Guidance systems (GNSS and RTK)

Guidance systems form the generic backbone technology for PA. They can be used by all kinds of equipment (e.g. tractors, combine-harvesters, sprayers, planters, etc.) and as part of a broad range of different agricultural applications. Guidance systems focus on precise positioning and movement of a machine with the support

Figure 4-1 Key precision agriculture technologies
Source: Dryancour, 2017.



of a Global Navigation Satellite System (GNSS). The equipment is becoming so smart that drivers barely have to do anything at all to get from Point A to Point B. Machines also till, plant, and apply fertilizer and pesticides while traversing those straight lines using a steering system. Even the most experienced drivers can make mistakes, but auto-steer takes the human error out of the equation in a way that has major benefits for farmers working their fields.

Guidance systems are most often used on tractors. Combine-harvesters are also being fitted with guidance systems to help keep equipment precise. While these systems are not standard equipment on new tractors, most are guidance system-ready, requiring additional investment in a GPS receiver with the level of spatial resolution desired. Guidance systems enable auto-steering, precise machine movement between plant rows, precision drilling and sowing, precision spraying and mechanical weeding.

Adoption of PA technology naturally leads to greater expenditures on machinery and equipment as these technologies are capital-intensive. Machinery also has a higher expense base (compared with labour costs) and more potential to influence overhead costs. Economic payback through field efficiency is critical for a farmer's decision to adopt guidance systems, but there are a number of other benefits that guidance systems are bringing to the end user.

Guidance systems work day or night, allowing faster, safer and more accurate field operations even when visibility is very low. This allows the user to get in the field whenever it is convenient, or to work around light and weather conditions that would be impossible with traditional guidance. Because the guidance system takes care of itself, the operator can watch other important operations, such as the condition of the crop, monitor feedback, the condition of the implements and obstacles in the field. Correcting a malfunctioning implement in the field can, in itself, enhance the steering product payback.

Because a guidance system puts farm implements on the most efficient course, it means the job will get done more quickly, and, clearly, the less time farm equipment runs, the less fuel will be used. Fuel expenses are just one way that guidance systems pay for themselves. Lowering the input costs is another way that farmers can save money. Farmers will spend less money on seed and less money on labour as the job will be done more efficiently and more quickly. An hour here or a few hundred seeds there all add up over the course of a season.

Although this technology was introduced in the early 1990s, significant studies at global level of the impact of guidance systems in agriculture are not yet available. To date, only individual research cases, mostly in the United States and Europe are measuring the impact of adoption and implementation on the field. An example is the work

CASE 3 USE OF AUTO-STEERING ON CROP AND SOYBEAN FARM IN THE UNITED STATES

MIDWEST LITMUS TEST

Substantiating a payback for Midwest row crop use of guidance system was a primary goal last year for ag economists at Purdue University. Jess Lowenberg-Deboer and then graduate student Matt Watson designed a study to evaluate and compare the economic impacts of using no guidance versus manual lightbar guidance, DGPS-based guidance, and higher accuracy real time kinematic (RTK)-based steering systems on a 1800 acre farm with a 50–50 corn–soybean rotation.

Using a 12-row planter, each system was measured on its ability to improve field efficiency and reduce skip and overlap, increase the number of hours worked and use techniques to control traffic patterns such as skip rows to increase efficiency.

The results were dramatic. Whereas manual guidance increased field speed by 13 percent, DGPS and RTK systems increased speed by 20 percent. Mean time spent in the field was reduced 11 percent using manual guidance, and an additional 6 percent using DGPS and RTK systems.

Doing the maths, Purdue determined that the same 12-row planter could handle an additional 800 acres in the given time frame using manual lightbar guidance, and an additional 1300 acres with GPS and RTK steering systems. Finally, and most importantly, grower net profits would be expected to increase by $9,700 annually using GPS steering systems and $4,500 for the more expensive, higher accuracy RTK steering systems.

Source: www.precisionag.com/in-field-technologies/guidance/automatic-steering-precision-agricultures-killer-app/

of Shockley *et al.* (2011), which modelled a commercial Kentucky corn and soybean farm under no-till conditions and applied a guidance system during planting and fertilizer application, resulting in cost-savings of approximately 2.4 percent, 2.2 percent and 10.4 percent for seed, fertilizer and tractor fuel, respectively, which is translated to greenhouse gas emission mitigation. Guidance systems such as lightbar and auto-steering can benefit crop growers by reducing working hours of operators in the field by 6.04 percent and reducing fuel consumption by 6.32 percent (Bora, Nowatzki and Roberts, 2012). In peanut digging operations, a study in Alabama during the 2005–2007 growing seasons revealed average net returns between 83 and 612€/ha for the use of auto-steering (Ortiz *et al.*, 2013). An economic analysis of farms adopting guidance systems showed that systems with inaccuracies below 2.5 cm are most profitable for larger farms, while systems with less than 10 cm inaccuracy are a better economic alternative for smaller farms (Bergtold, Raper and Schwab, 2009).

The economic benefits of guiding systems in the UK were estimated for a 500 ha farm to be at least at 2.2€/ha (Knight, Miller and Orson, 2009), but the benefits grow if other more complex systems are adopted, such as controlled traffic farming (CTF) (2–5 percent), which would lead to additional returns of 18–45€/ha for winter wheat cultivation. In Germany, economic benefits from savings of inputs were assessed at 27€/ha for the case of winter wheat. CTF typically releases 57–115 €/ha extra profit, including the required investment, cost savings and increased yields.[107] The implementation of GNSS provides economic advantages of up to 28€/ha from input savings (Shockley *et al.*, 2012). If a guidance system is already installed, the economic advantage of the automatic section control is even higher. Using CTF can decrease fertilizer use by 10–15 percent for narrow-spaced crops and pesticide reduction can reach 25 percent. Tullberg (2016) has analysed the impact of CTF in GHG emissions directly and indirectly, by reducing energy inputs, facilitating zero tillage and increasing fertilizer efficiency. Primarily, he referred to an approximate reduction of tractor fuel requirements of 40 percent and 70 percent while using uncontrolled traffic zero tillage and controlled traffic zero tillage farming, respectively, in comparison with conventional tillage. Horsch Company (Balafoutis et al., 2017) pointed out that fuel use for crop establishment with CTF is reduced by at least 35 percent, while Jensen *et al.* (2012) estimated that it may be possible to reduce costs of fuel by 25–27 percent in cereals because of less overlap.

Although the economic impact of guidance systems is clear, they are expensive and not all farmers can afford them. Farmers identify up-front cost as the most frequently mentioned disadvantage of machine guidance. Guidance systems have scalable cost according to the accuracy obtained from each system. The cost starts from 1,320€ if a GNSS device is already held by the farmer. Commercial applicators that require a system to combine recording of all operations (to different customers) together with full navigation can reach more than 12,770€ (Grisso *et al.*, 2009). In countries where most of the farmers are earning less than US$2 per day and cultivate less than 2 ha, these technologies are not profitable. More affordable could be VRT combined with UAV application services provided by companies, thus costs will be decreased and such services are available for smallholders.

4.1.2.2 Variable rate technology (VRT)

VRT in PA is an area of technology that focuses on automated application of materials to a given landscape. The way in which the materials are applied is based on data collected by everything from drones and satellites, AI, IoT and hyperspectral imaging. These materials include fertilizers, chemicals, seeds and water, with all aiming to optimize crop production. There are many forms of technology used in VRT for PA. VRI stands for precision irrigation, VRS for precision seeding, VRNA for precision nitrogen fertilizer application and VRPA for precision pesticide application. Regardless of which variable rate application technology is used, it is important to understand the general way in which this technology is applied.

The capital cost of farm implements equipped with VRT capabilities is fairly high, especially when specialized machinery with integrated sprayer or seeding equipment must be scrapped. For this reason, many producers, particularly smallholder farmers, have opted to hire service providers when choosing VRT. With the fast pace of IoT development and price decrease of the equipment for irrigation, a more feasible option for smallholder farms is VRI that optimizes maximum profitability on irrigated crop fields with topography or soil variability, improves yields and increases water use efficiency (Case 4).

A VRT system can help to automate the agricultural process. The more automation and precision that a farm introduces to its operations, the more money can be saved through higher production and efficiency. Multiple sources, project-based and mostly large-scale farms from developed countries present various economic benefits of VRT.

Applying VRI mostly has impact from an environmental point of view. The contribution of VRI to GHG emission abatement lies in reduction of water, leading to lower pumping energy needs and proper irrigation scheduling, preventing extreme soil water availability to boost N_2O

CASE 4 APPLYING SMART IRRIGATION SYSTEM IN GREECE BASED ON FAO METHODOLOGY

IRMA_SYS

IRMA_SYS operates at the plain of Arta (Region of Epirus, Greece). The main objective of the project is to provide recommendations to farmers on irrigation management through use of an integrated IoT system, with the aim of optimizing use of water and energy and saving labour. More precisely, IRMA_SYS uses ICT to collect, store and process necessary data from point sources (agrometeorological stations) and transform them to maps that cover a big area. In this way, basic weather data and reference evapotranspiration are available for each point inside the covered area. This information is then combined with information provided by the users for their fields and the irrigation events they apply, to provide irrigation management recommendations. IRMA_SYS covers the 20 000 ha of the Arta plain in Greece. It uses real time (10-min averages) data from six agrometeorological stations, that were deliberately placed, after a relevant study, all around the area covered. Data are sent via VHF and GPRS to a communication centre, which is connected to the system's server. All this information, along with data concerning irrigation events (inserted by the user) and weather forecast data (provided by the National Observatory of Athens (on a 6.5×6.5 km grid basis), is used to estimate irrigation water requirements on hourly and daily time steps. A modification of the FAO Penman-Monteith method is used by the software for this task. All the software has been developed as open source. The service is available in both Greek and English languages.

IRMA_SYS leads to conscious building regarding rational water use in the framework of irrigation. The users understand the significance of knowing basic facts about their irrigation system (flow rate, uniformity, etc.), the ability of each soil type to store water and the actual crop water needs. Use of the system leads to water savings (which are more significant for high water-consuming crops, for example it is 5 percent for olives, 15 percent for citrus and at least 30 percent for kiwi-fruits) and the respective energy and labour savings. For example, the kiwi-fruit crop covers an area of 1200 ha at Arta and needs 600 000 m^3 of water for irrigation every year. IRMA_SYS already provides potential savings of at least 30 percent for this crop, which corresponds to around 200 000 m^3 of water per year. In addition, irrigation water management organization in the area where IRMA_SYS is applied can be used to document decisions regarding water allocation in other participatory systems managed in the same area.

The installation cost of IRMA_SYS (IRMA_SYS in not to be installed in single fields) varies between 5 and 20€ per hectare depending on the terrain, the number of crops in the area, the availability of agrometeorological stations and background information (i.e. soil maps, etc.). The annual maintenance cost has to be calculated individually for each case, but to give an idea of the cost, for the plain of Arta (an area of 20 000 ha in which the system currently operates), this is 60000€ per year. Use of IRMA_SYS does not require any hardware at the field. After the setting of each field, the user needs only a mobile phone or a computer, etc., to input the irrigation event data and to access the recommendations. Thus, the system is available to all interested, which makes it socially fair.

Source: http://irmasys.eu/

emissions. Computer simulation studies comparing conventional and "optimized" advanced site-specific zone control by centre pivot irrigation have reported water savings of 0–26 percent (Evans *et al.*, 2013).

VRI systems can provide 8–20 percent reduction in irrigation water use (Sadler *et al.*, 2005). La Rua and Evans (2012) using centre pivot speed control determined that irrigation efficiency (the ratio between irrigation water actually used by growing crops and water diverted from a source) can be increased by more than 5 percent. If speed control is also combined with zone control, then the irrigation efficiency can be further improved by 14 percent. The HydroSense project (HydroSense 2013) applied VRI in three experimental fields with cotton in Greece and showed that variable irrigation in cotton cultivation achieved 5–34 percent savings in water consumption. Lambert and Lowenberg-DeBoer (2000) reported economic benefits through use of VRI, because of higher corn yields and better water use efficiency; however, these benefits were not quantified. As mentioned above, VRI systems can add significant costs to the farm, but additional benefits have been identified after installation of such systems, such as possible yield

CASE 5 IOT FOR WATER IRRIGATION IN SOME LATIN AMERICAN COUNTRIES

IMPROVING WATER USE IN DRY AREAS

Telefónica and FAO

Application of the IoT the digital interconnection of everyday objects to the Internet to the agricultural sector aims to optimize processes and make more efficient use of natural resources. FAO and Telefónica are working on a pilot water efficiency project with communities in El Salvador and Colombia, using a combination of specialized hardware, cloud storage and data processing that generates recommendations to facilitate decision-making for farmers on issues related to irrigation for efficient use of water.

The first four relate to crops of cucumber, bell peppers, papaya and tomato in different districts of El Salvador, and were launched in September. This will be followed by two cotton projects in Peru, and a potato project in Colombia during October. And, finally, in November the FAO and Telefónica will launch projects focused on avocado and plantain in Colombia.

The pilots will run at least until the end of 2019 so that results can be compared from one year to the next, although some crops can be repeated twice a year or more. The FAO's partnership with Telefónica consists of a first phase running through 2021. Telefónica has claimed 20 percent savings in water and power for irrigation as a result of AI technology developed at its R&D centre in Chile.

Source: https://www.bnamericas.com/en/news/ict/telefonica-and-fao-launch-latam-water-efficiency-pilots

increase, workload reduction, water use decrease and even pesticide use saving, especially in climatically unfavourable years such as in big droughts (Booker *et al.*, 2015; Evans & King 2012).

A review by Trost *et al.* (2013) compared N_2O emissions from irrigated and non-irrigated fields showing an increase of N_2O emissions (about 50 percent to 140 percent) under irrigation, in most case studies. This shows that VRI may significantly influence N_2O emission from irrigated soils. VR irrigation systems can also assist irrigation scheduling combined with meteorological prediction models and fertilization schedules to keep soil water availability at such levels to avoid provoking more GHG emission production through N_2O.

VRS of winter wheat can increase yield from 3 percent compared with uniform seeding.[108] Another study showed that farmers using VRS have achieved an average winter wheat yield benefit of 4.6 percent over and above farmers drilling at a flat rate. This makes an average winter wheat yield benefit over the four years of study (2011–2014) of 6.45 percent (European Parliament, 2014). Corn yields can be increased by 6 percent using VRS.[109]

Several authors have analysed the impact of VRNA on farm productivity and economics. Tekin (2010) estimated that VRNA can increase wheat production between 1 percent and 10 percent, offering savings in nitrogen fertilization between 4 percent and 37 percent. Mamo *et al.* (2003) executed an experiment for three years (1995, 1997, 1999) in corn fields in rotation with soybean in Minnesota, USA, and found a profit increase of 7 to 20.25 €/ha for corn when using VR fertilizer application compared with uniform application because of a reduction in the use of fertilizer.

There has been significant interest in the amount of pesticide that can be saved, reported to range from 11 percent to 90 percent for herbicide use in different arable crop types (Timmermann *et al.*, 2003; Gerhards *et*

CASE 6 APPLYING VRT FOR SEED AND FERTILIZER IN AUSTRALIA

A four-year trial conducted by SARDI at Minnipa, a low rainfall region of South Australia, commenced in 2008. This found that varying inputs to soil type can pay off, but the degree of variation is linked to the season. Low, medium and high seed and fertilizer rates were sown in alternating 9-metre strips across a paddock. The low rate consisted of 55 kg/ha of seed and nil DAP and foliar N. The standard rate consisted of 65 kg/ha of seed, 40 kg/ha of DAP and nil foliar N, while the high rate was 65 kg/ha of seed, 60 kg/ha of DAP and 10 kg/ha of foliar N. The paddock was then segregated into three production classes, good, medium and poor, using a combination of yield, EM38 and elevation maps.

The poor class produced lower grain yields than the good and medium classes, irrespective of treatment. In 2010, grain protein levels were higher for the medium class than for the good or poor classes, but there was no difference in grain quality in the three years. To assess whether varying rates in each of the production classes listed above were more lucrative than applying one of the three blanket rates of inputs, gross margin analysis was applied. Two VR approaches ("Go for Gold" and "Hold the Gold") were compared with each of the gross margins for the blanket input treatments (high, standard, low).

The "Go for Gold" treatment aimed to increase overall profitability by reducing inputs on areas with poorer yield potential and increasing inputs on areas of higher yield potential. The "Hold the Gold" low-risk approach kept inputs at standard in the good class and low in poor and medium classes. In 2010, "Hold the Gold" produced a higher gross margin than any of the three blanket treatments (high, standard, low). The low-input blanket approach was the most profitable of the blanket treatments at $631/ha, slightly more than the standard input blanket approach at $630/ha and the high-input blanket approach at $613/ha. The trial showed that in low-rainfall areas, VRT can help growers minimize risk and cash in on nutrient reserves in poorer areas, while looking after the more consistent areas of the paddock.

Source: https://grdc.com.au/__data/assets/pdf_file/0026/207791/grdc-fs-variablerate-application.pdf.pdf

al., 1999). Other work recorded pesticide use reduction in perennial crops at between 28 percent and 70 percent (Solanelles *et al.*, 2006; Chen *et al.*, 2013). VRPA can also cause reductions in insecticide use by 13.4 percent in winter wheat (Dammer & Adamek 2012), while spray overlap can be significantly decreased with impact on the total pesticide use (Batte & Ehsani, 2006). The impact of the high pesticide reduction shown from the literature is environmentally significant, but, in terms of GHG emission reduction, the contribution of this technology to the total agricultural effect is slight.

To conclude, in smallholder farms, savings are highest from VRT because they optimize all inputs such as seeds, water, fertilizer and pesticides. Guidance systems can assist VRT but are also helpful for crop production by themselves.[110] Some PA technologies are already highly affordable and thus available to smaller farms thanks to smartphones or tablets and their applications. Such applications can directly signal a problem in the field or connect to an online service for further probing.

Regarding the benefits of variable rate N application, several studies have claimed, after economic and statistical analyses over a period of 10 years, that there is no statistically significant economic advantage of sensor-based fertilizer application (Boyer *et al.* 2011). This conclusion is consistent with earlier observations (Liu *et al.*, 2006), who calculated profitability below 8€/ha, which hardly covers the costs of application. Studies in Denmark showed no economic effect of sensor-based fertilizer redistribution in the field according to high and low yield zones (Oleson *et al.* 2004). Potential explanations of the small benefits of variable rate nitrogen application may be the slope of the profit function around the economic optimum (Pannell, 2006), perhaps because the application rate is already near optimum, therefore VR only has a marginal effect. This is not a valid conclusion for all crops under all growing conditions, as it has been demonstrated that the economic margins of precision fertilizer applications increase with increasing fertilizer and crop prices (Biermacher *et al.* 2009).

Therefore, adoption of PA is linked not only to adequate technologies, but also to a series of factors related to the availability and hardship of basic infrastructure (access networks and technology), economic, cultural, age and economic incentives. Knowledge of new technologies is, of course, important to continuing investment in innovation and research to develop increasingly precise, adequate and sustainable technologies, but equally important is the effort in the regulatory and policy framework to improve infrastructure conditions in rural areas, access to credit, as well as the effort of the agricultural sector to create the necessary skills and

CASE 7 PRECISION AGRICULTURE APPLICATION ON SMALLHOLDER FARMS IN KENYA

PRECISION FARMING INCREASES YIELDS BY 60 PERCENT IN KENYA

More than 20 000 smallholder farmers from former Western and Rift Valley provinces are recording over 60 percent increase in sorghum millet and other cereal yields on the most infertile soils in sub-Saharan Africa. Dubbed precision farming, or microdosing, the process involves the application of small, affordable quantities of fertilizer with the seed at the time of planting or as a top dressing three to four weeks after the seed sprouts. This ensures that the tender crop uses the fertilizer exhaustively, in sharp contrast to spreading fertilizer over the field, which means many crops compete for the same portion of fertilizer sprayed. Rather than asking how a farmer can maximize yields or profits, microdosing asks how a farmer can maximize the returns on a small initial investment, which might grow over time, turning deficits into surpluses. Farmers who use microdosing apply 6 g doses of fertilizer, about a full bottle cap or a three finger pinch, in the hole where the seed is placed at the time of planting.

According to the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), this translates to about 67 pounds of fertilizer for every 2.5 acres. This technique, the research institution says, uses only about one-tenth of the amount typically used on wheat. Yet the Kenyan crops are so starved of nutrients, such as phosphorous, potassium and nitrogen, that even this micro amount often doubles crop yields. Farmers in various areas of the country where microdosing is taking shape have also adopted innovative techniques to apply microdoses of the appropriate fertilizer. Whereas farmers in the Rift Valley use fertilizer measured out in an empty soft drink or beer bottle cap, in Central Kenya the farmers measure the fertilizer with a three-finger pinch and apply in it the same hole in which the seed is sown.

Source: http://agroinnovation.kenyayearbook.co.ke/precision-farming-increases-yields-by-60-percent/

knowledge. All these elements must go hand-in-hand so that this next agricultural revolution is carried out in the broadest and best possible way.

4.1.2.3 Precision livestock farming (PLF) technologies

PLF supports real-time monitoring of production, health and welfare of livestock to ensure optimal yield. Advanced technologies allow for continuous monitoring and can facilitate farmers with decision-making to ensure improved health of animals. Farmers can use wireless IoT applications to collect data regarding the location, well-being and health of their cattle. This information helps them to identify animals that are sick so they can be separated from the herd, thereby preventing the spread of disease.

Livestock IoT includes not only animal climate monitoring and control, but in some cases includes field monitoring for optimal feeding practices (Bhargava, Ivanov and Donnelly, 2015). The Livestock Identification and Traceability Systems (LITS) enables the tracking of animal movements. The RFID are one element (the visible one) of the LITS. RFID is the most common IoT technology found in PLF. RFID tags, acting as enhanced barcodes, enable the tracking of animals. Recent research, following the IoT paradigm, has combined more than one sensor to enrich the information of animal status whenever this is recorded through its RFID (Maksimovic, Vujovic and Omanovic-Miklicanin, 2015).

RFID technology is not limited to identification of animals, in particular by adding sensors to the active tags it can be used to monitor body temperature and ruminal variables. To date, identifying health problems in animals has often been limited to visual symptoms. On identification of any symptoms, a rectal thermometer can then be used to determine the animal's body temperature. This limits disruption to animals that are not ill. Using RFID systems the body temperature of an animal can be detected remotely, and diseased animals can be identified before any disease symptoms appear. RFID can also lower labour costs as ranchers can locate their cattle with the help of IoT-based sensors. Hence, this technology has the potential to increase many aspects of performance in care of animals (Dye *et al.*, 2007). Main constrain of using RFID is the current Low Frequency RFID used in animal identification, thus making the reading distance limited. This means the transponder cannot be activated from a long distance Because difficulties can be encountered using GPS systems indoor and for "hidden" areas (Bekkali, Sanson & Matsumoto, 2007), RFID systems have come to the forefront in identification and tracking of animals (Farid, Nordin & Ismail, 2013, Gu, Lo & Niemegeers, 2009). Australia, Canada, Japan and many other developed countries, have established RFID-based systems for monitoring and identification of animals and animal products. Plastic tags are still widely used in cattle and small ruminants, even in developed countries. The use (and cost-effectiveness) of RFID depends on the objective and number of readings (i.e. for performance recording and herd management).

4.1.2.4 UAV (drones)

The use of drones in agriculture is extending at a brisk pace in crop production, early warning systems, disaster risk reduction, forestry, fisheries, as well as in wildlife conservation. In practice, IoT offers for agricultural needs two types of drones: ground-based and aerial-based. To gather the necessary information, farmers input the field data, including ground resolution and its altitude. As a result, a drone provides details on plant counting, yield prediction, health indices, height meterage, the presence of chemicals in plants and soil, drainage mapping and various other data. Among the examples from the sphere of the IoT for agriculture, the basic directions of drone assistance include soil and field analysis (with 3D maps for seed planting predictions), planting (by providing the needed nutrients), crop spraying (with ultrasonic echoing and lasers to adjust altitude and avoid collisions), crop monitoring (through providing time-series animation instead of static satellite images), irrigation (having sensors to reveal dry areas) and health evaluation (taking crop scans to identify the lack of green light and NIR light). In other words, drones take care of the full cycle of crops.

For mapping a larger area, a larger workforce and time are required to collect the data. Smaller areas, such as those that range from 1 to several hectares, are likely best completed with terrestrial surveying tools such as RTK GNSS equipment. For areas as much as 1 km^2, drones are great tools that can produce very high-resolution data. However, drones are generally limited in endurance and airspeed, which reduces the amount of area they can cover per flight. It would take multiple flights, battery

CASE 8 USE OF RFID AMONG COWS IN PAKISTAN

COWLAR

Cowlar is a wearable technology for cows, designed to help farmers more easily track the health, fertility, location and general activity of their cattle.

Despite being one of the world's major milk-producing countries, Pakistan's average milk yield per cow is far below that of other nations. The founders of Cowlar, a start-up based in Islamabad, Pakistan, believe that by increasing the efficiency of each farmer's herd by even 5 percent, more than US$1 billion could be added to the country's economy. An easy-to-fit collar, the Cowlar is waterproof and has a six-month battery life. Using motion sensors, the collars wirelessly send data to farmers via a solar-powered base and cellular service towers. Simple installation of a solar-powered base unit is required on the farm, and the Cowlars are then strapped to the cows. The Cowlars measure the temperature, activity and behaviour of the cows and send that data via the base station to servers, which process the data based on complex algorithms generated from vast expert knowledge to provide the best actionable recommendations.

Depending on their personal preference, farmers can access their herd's information via text, automatic phone call and through an online dashboard. Currently the collar costs US$3 monthly subscription fee. The cows get better care, produce more milk and the technology can help farm owners improve their profit margin by up to 30 percent.

Source: www.cowlar.com

swaps and logistics to complete a 1 km^2 aerial survey. Manned aircraft can collect relatively high-resolution data, but the economies of scale do not really justify their use unless the area is rather large, perhaps starting around 20 km^2.

Today, images from drones can indicate the development of a crop with precision and can locate underperforming areas, enabling better crop management. Drones can be outfitted with countless combinations of sensors to fit a farmer's needs. Various sensors can also be used to pick out healthy plants from the unhealthy ones, while others simply compare colour differences in crops that are undetectable to the human eye. Some sensors detect heat or moisture to determine crop health. All of this ultimately helps growers catch problems early and allows them to continue to improve the productivity of their crop.

As a result of their large spectrum of usage, drones have diversified impact on the agriculture sector. Mostly their impact is visible on input application and growing stage of the crop based on type of purpose and sensors attached. The drones are equipped with sensors to collect data that can be analysed for more efficient use of chemical inputs (pesticides and fertilizers) and water (drip irrigation). They also allow for selection of interesting traits of plants in the field (e.g. tolerance to drought, salinity or stresses, resistance to pests or

CASE 9 USE OF UAV FOR SPRAYING COTTON IN CHINA

AGRAS UAV

Crop treatments from individual drones or unmanned aerial vehicles (UAVs) are already widespread across Asia. The Chinese DJI company's latest model, the eight-rotor Agras MG-1, goes in another direction entirely – it is designed for agricultural use. The primary use of the Agras is spraying crops, with the ability to cover between 7 and 10 acres an hour. The drones used are approximately 2 m in diameter, weigh about 20 kg and can carry a 10-litre payload to treat about 1 hectare an hour. Active radar systems and real time knowledge (RTK) GPS are programmed into the drone, which then flies a pre-set route at location accuracies down to 1 cm. Agras is over 40 times more efficient than manual spraying.

The Jiuzhou Aerial Spraying Team led a project in Tacheng, Xinjiang, using the drone for spraying tomatoes over 3295 acres in 20 days while saving farmers 1800 CNY per acre. Also, they used drones to spray cotton for farmers in the Bortala area, spraying 26 acres of cotton in 4.5 hours, on average, 6.7 acres were sprayed per hour, earning farmers 1600 CNY. This means, they could spray at least 60 acres of cotton per day and earn over 3000 CNY. Also, the Team found that fan nozzles used by the MG-1 had much better atomizing effect than cone nozzles on a tractor and airflows generated by propellers sent droplets around leaves reaching lower down the cotton, increasing the de-leaf rate. Additionally, as tractors often damage a number of plants or knock off cotton bolls, the use of a drone for spraying increases cost-effectiveness further.

Source: https://forum.dji.com/thread-84286-1-1.html diseases) to use the selected plants in crop breeding programmes to face challenges such as climate change. The impact on food safety and crop production is high because they enhance agricultural yields.

In 2014, drones helped farmers in China to cut use of pesticides by half, reduce water consumption by almost 90 percent, and reduce labour and material costs by 70 percent.[111] Drones are faster than humans as they can apply pesticides up to about 132 acres of farmland each day in northern China, whereas one person is usually able to cover a maximum of 5 acres per day.[112]

Drones equipped with the right sensors can identify which parts of a field need more water. Farmers can use this real time information to make the proper adjustments to their fields and use their resources optimally and without waste. Additionally, the information gathered by the drones can help farmers perfect the level of water in the field to create peak growing conditions tailored to specific crops. When crops are damaged from storms and other unpredictable weather conditions, drones equipped with suitable imaging equipment can be used to estimate crop loss. This helps to speed clean up and repairs while mitigating both risk and field maintenance costs for the farmer.

Drones can also be equipped with equipment that gives them the ability to scan the ground and spray the precise amount of chemicals at the perfect altitude needed for any application. This dramatically reduces the amount of chemicals used and virtually eliminates overspray. The ability of a drone to make real time adjustments greatly improves efficiency over outdated and haphazard crop dusting.

In terms of social impact, drones can replace labour-intensive and potentially harmful use of backpack sprayers and similar equipment, in situations where terrain and/or ground conditions rule out the use of conventional or even specialist vehicles, thus they save time and prevent labour from exposure to hazardous risks.

Despite some scientific findings there are no relevant data for detailed impact of drones in the agriculture sector at national or regional levels. Existing and available data generated worldwide is mostly based on individual small-scale projects.

4.1.3 BIG DATA, CLOUD AND ANALYTICS AND CYBERSECURITY

"Big Data" describes extremely large data sets, with different types of representation, such as text, numbers, pictures, video, etc., increasing complexity and diversity. These data may be analysed computationally to reveal patterns, trends and associations, to describe behaviour and interactions. The overarching characteristics of Big Data that apply to most disciplines are the 4Vs: Volume, Velocity, Variety and Veracity. Note that Big Data are normally sourced from industry, academia and government, it being more common to start using data generated by the users of farm equipment, mobile phones and social media.

In 2015, investors poured $661 million into 84 agricultural start-ups designed to help farmers transform agriculture into the next Big Data industry (Burwood-Taylor, Leclerc & Tilney, 2016). In the USA, venture capitalists spent US$3 billion on "agtech" (digital technology in agriculture) in 2016, with 46 percent of investors focusing on Big Data and analytics (Walker *et al.*, 2016). The new device, sensors and IoT, equipment and satellite capabilities are capturing minute field-level data such as soil moisture, leaf greenness, temperature, seeding, fertilizer and pesticide spraying rate, yield, fuel usage and machine performance. Data are transforming the entire agriculture value chain, collecting, processing and analysing data to maximize their yields and reduce the need for agricultural inputs and natural resources. New digital tools are enhancing transparency into how crops are grown, livestock is produced, and food is processed and distributed. Big Data analytics is simply the process by which we collect, manage and analyse this large volume of structured and unstructured data. The aim of this analytic process is to discover patterns about anything from consumer decisions to market trends that can inform business decisions and strategies.

The global agriculture analytics market size will grow from US$585 million in 2018 to US$1,236 million by 2023, with a Compound Annual Growth Rate (CAGR) of 16.2 percent during the forecast period.[113] The major drivers include the global demand for food, increasing farm productivity, and optimizing agricultural production and farm management practices.[114] The important areas where this market will invest are:

a) livestock analytics applications include feeding management, heat stress management, milk harvesting, breed management, behaviour monitoring and management, and others. The livestock agriculture includes varied tasks performed daily, which generate large volumes of critical data about animals.

b) agricultural analytics solutions to correlate a wide variety of data to obtain valuable insight for increasing productivity. Crop yield depends on multiple factors, such as weather parameters, soil condition, fertilizer application and seed variety. It becomes very challenging for farmers to identify the critical

CASE 10 CGIAR BIG DATA PLATFORM SUPPORTS SMALLHOLDER FARMERS IN COLOMBIA

CGIAR BIG DATA PLATFORM

Catastrophe aborted: the case of rice farmers in Colombia

The CGIAR platform is already showing results of potential benefits for smallholder farmers, such as for the Colombian Rice Farmers Federation. After multiple seasons of challenging rain patterns, rice farmers in Colombia were struggling to know when to plant their crop. Depending on whether there was going to be above average or below average rainfall, farmers had to decide whether to plant earlier or later in the season. If there was going to be too much rain, they might decide not to plant at all that season. The risks and trade-offs of these decisions are significant: if a farmer invests in planting a crop and the harvest fails, the financial impact of that loss can have serious consequences for the farmer's business. But how can a farmer predict how much rain there will be?

In a pilot project for the Platform for Big Data in Agriculture, researchers from CGIAR were able to help the rice farmers by aggregating local weather data as well as rice production data for the region. They ran this large volume of data through a climate model that could project the prevailing trend of rainfall for the region as well as analyse the viability of a rice crop in varying amounts of rain. For that season, the researchers recommended that the farmers delay planting until the next season. And sure enough, there was a huge amount of rain that season – enough rain to ruin a rice crop. Through the use of this Big Data methodology, the CGIAR platform was able to respond to an urgent problem and provide critical guidance to help these farmers.

Source: https://cgspace.cgiar.org/bitstream/handle/10568/92045/Data_Driven_Farming_ORMS4502.pdf?sequence=1

factors from large data sets that can impact their farm productivity.

Adoption of an agriculture analytics solution is more attractive for large farms than for small and medium-sized farms, because of affordability and high economies of scale. Thus, the size of a large farm carries out high-level commercial operations that generate large volumes of data, generating attractive opportunities for service providers to help large farms manage and use data.

The major vendors in the market offering agriculture analytics solution and services across the globe include Deere & Company (US), IBM (US), SAP SE (Germany), Trimble (US), Monsanto Company (US), Oracle (US), Accenture (Ireland), Iteris (US), Taranis (Israel), Agribotix (US), Agrivi (UK), DTN (US), aWhere Inc. (US), Conservis Corporation (US), DeLaval (Sweden), Farmer's Business Network (US), Farmers Edge (US), GEOSYS (US), Granular (US), Gro Intelligence (US), Proagrica (UK), PrecisionHawk (US), RESSON (Canada), Stesalit Systems (India) and AgVue Technologies (US).

There is clear evidence that Big Data, analytics and PA are transforming the way agricultural operations are carried out, as well as the integration of production processes with logistics and commerce (Pham & Stack 2018). However, the implementation of Big Data in agriculture brings challenges and concerns (Jakku *et al.*, 2018) reported in Australia: (a) confidence, (b) infrastructure and (c) global competence. Making a generalization of these concerns and adding other elements from the use of data and bid data in other areas, it is possible to indicate the following identified risks.

a) Privacy, data rights and trust. Privacy and trust in the context of Big Data is very different for large companies and for small and medium farmers. In the first case, the important factor is confidence in the processes of data storage and the governmental rules and restrictions. However, in the second case, small and medium farmers, the most relevant considerations have to do with maintaining the rights of individual farmers and making sure that the benefits go back to the producers;

b) Regarding infrastructure, the biggest challenge is the lack of connectivity (Internet and high-speed networks) in rural and remote areas, as well as the lack of data management capabilities. This generates an important advantage for corporations, because they are more likely to have access to the necessary infrastructure, but not so for medium and small farmers;

c) Global competition as a risk in the implementation of big data corresponds to the need to remain competitive, because this type of technology and its use generates competitive advantages that are difficult

to maintain and acquire, and with it the possibility of obsoleteness.

Additionally, and as an extrapolation of effects in other domains, risks associated with privacy and cybersecurity have been identified, as well as the asymmetries that could be generated for those who have access to said data.

a) Cybersecurity and data protection. The rapid growth and adoption of big data and analytics has created the possibility of cybersecurity threats. This occurs not only at the level of hacker attacks, but also the possibility of modification and/or leakage of the data, declassifying personal data, as well as those relevant to the different stakeholders. Finally, the possibility to stop, or worse, the introduction of unsuitable agriculture equipment operation or poor decision-making, is a threat that must be addressed. Cybersecurity and data privacy must be a priority, otherwise it could affect, malfunction and/or destroy relevant information;

b) Marketers and traders expected that Big Data would allow them to better predict the demand and prices of agricultural products. This could exacerbate the commercial advantage that marketers and traders can exercise over growers. Consequently, Big Data applications could generate asymmetries in the value chain, where growers would be more exposed.

Smallholder farmer data are highly fragmented, because methods to capture, store and use data are not standardized. According to an assessment (USAID, 2018), the data and the technology (hardware and software) already exist to solve many constraints faced by small farmers, but these are fragmented and not all service providers have equal opportunities to access. Use of Big Data could bring together fragmented data and resources and diverse service providers for a more supportive farmer ecosystem.

The intelligent agriculture cyberinfrastructure must integrate sensing (e.g. GPS, remote sensing, field sensors, etc.), data aggregation, scalable data analytics and visualization. Sensing will consist of stationary and mobile devices (e.g. smartphones, air/ground robots) that measure local environmental conditions (e.g. weather, soil moisture and composition), collect multispectral imagery (e.g. plant health, animal location, crop maturity), and track implement and input use (e.g. irrigation, pesticide, tractors) among others. Data systems will consist of public cloud services and on-farm or community-based edge cloud systems that implement a wide range of tools (e.g. open source and proprietary) for extracting actionable insights from farm data. Edge clouds are small computing “appliances” that operate similarly to public clouds yet preclude the need for Internet connectivity (and costly data transfer) while giving farmers real time, localized decision support and control over the privacy and sharing of their data. Public clouds will facilitate large-scale batch data analytics and sharing of anonymized information across farms.[115]

Finally, the data surrounding the crop life cycle and farming practices that such cyberinfrastructure must support are vast and disparate in type (e.g. imagery, time series, statistical), structure (e.g. hand-written, digitized) and scale (e.g. spatial and temporal, plant-to-global levels). Moreover, these data sets are incomplete, interdependent, volatile, imprecise and generated by a vast diversity of devices (e.g. drones, farm workers, sensors and Internet services) not designed to address future (and unknown) challenges. New techniques for data fusion, which are amendable to analysis, are needed that integrate multidimensional data from multiple sources to form standardized and useful representation of a physical object or system.

Even though the promise of Big Data and analytics is important, there remain barriers to realizing this potential of Big Data in agriculture. These include: (a) lack of ability to aggregate and interpret data in such a way that it results in useful decision support tools for farmers; (b) awareness, training and knowledge to farmers in how to use new tools; (c) interoperability of data and standards to make a big data system widely useful. Finally, the need to achieve an institutional framework that regulates the acquisition, storage and use of Big Data among the different actors (farmers and other actors), to establish rules that facilitate extraction and equal exchange of value of big data (Lioutas *et al.*, 2019).

CASE 11 DIGITAL INTELLIGENCE PLATFORM FOR SMART FARMING OPERATIONS

PROAGRICA:

Seeding a new era of precision

Did you know, increased yields mean a single farmer feeds six times the number of people they did in 1960? And with limited extra land available, maintaining those increases over the coming decades calls for the exceptionally efficient use of data and technology through evidence-based agriculture. That's why analytics innovations like Proagrica's Agility are so important. They helped the company build an insights platform that's giving farmers new levels of insight into their farming operations – and pushing at the boundaries of the precision agriculture revolution.

THE CHALLENGE: HOW TO HARVEST A WIDE RANGE OF AGRICULTURAL DATA INSIGHTS

Today, the average farmer feeds nearly six times the number of people they did in 1960. And by 2050 they'll feed more than two-thirds as many again. These extraordinary efficiencies are only possible with the high yields that technology-driven precision agriculture can deliver. That's something that Proagrica, who provide high-value insights to the global agriculture industry, know better than any. And when they came to develop Agility, a new insights platform for farmers, they wanted to put on-farm data-driven evidence-based production front and centre. But how to bring such a wide range of different farming data sources together? And how to surface the insights in a way that those at the forefront of sustainable agriculture – the farmers – could actually use?

HOW THEY HELPED: DIGGING DEEP INTO THE DATA

Their team of data experts worked with the company right from the initial germination of the concept through to fruition. The first challenge was to bring such a large amount of information together in a usable way. They took the data Proagrica were collecting from sources as diverse as weather reports, soil types, crop types, machinery operation, and other on-farm data – even satellite and drone data. Then this was merged into a single big data repository and the entities and their attributes were organized in a canonical model. That gave Proagrica a solid data foundation for their Agility platform. But just as vital to the success of the project was harvesting the insights for the farming community. Using Elasticsearch, NodeJS, React, and HPCC, they built a user interface and data service for the platform to put actionable insights right in the hands of the people who need them.

THE RESULT: CHEERS TO NEWFOUND FLEXIBILITY

Proagrica's new Agility platform is helping farmers grow their profitability through evidence-based precision agriculture. With its in-season analytics based on crop protection, planting, cropping stage, nutrition, farming operations, and region, it's giving farmers deep insights into the trends, threats, and opportunities that can make or break their businesses. Moreover, Agility's enriched market insights are providing a much greater level of visibility into the whole farming supply chain, as well as enhanced traceability to provide better provenance data. And that's not just helping farms make better decisions for their own businesses, it's helping them become ever more effective stewards of some of the planet's most valued environmental resources.

Source: https://www.searchtechnologies.com/sites/default/files/Search%20Technologies/case%20studies/PDFs/Proagrica-Precision-Agriculture.pdf

4.1.4 INTEGRATION AND COORDINATION (BLOCKCHAIN, GLOBAL ERP, FINANCING AND INSURANCE SYSTEMS)

The digitalization that has taken place in agriculture and the value chain allows the data and information generated in the productive and administrative processes, as well as in the value chain (coordination), to be integrated into common platforms, allowing for possible integration of management and decision support. In this line, it is possible to identify technologies that integrate processes and information at the level of productive units, such as ERPs with agricultural specialization, and those that coordinate the different stages of the value chain. In recent years, platforms have emerged that allow integration of operations, processes, data and information with the value chain in the agricultural sector. Below is an analysis of these cases, identifying the existing technology and the impact they have had or their potential impact.

4.1.4.1 Enterprise resource planning in agriculture

As recently as 10 years ago, traditional ERP was viewed as limited in regard to the agriculture industry (Verdouw, Robbemon & Wolfert, 2015). In fact, traditional ERP was rarely designed to address the specific needs of the farmer, lacking flexibility required for an industry that can thrive or fail based on the whims of nature, or on the whims of a marketplace characterized by uncertainty.

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. A scalable ERP for the agriculture industry could help in efficiently maintaining business operations, ensuring product quality, tracking money accounting, facilitating inventories or offering supply chain management and distribution. Many ERP offerings, such as Infor Syteline CSI,[116] ERPNext,[117] Agrivi, Granular, Trimble, FarmERP, FarmLogs, Agworld, AgriWebb and Conservis,[118] have embraced the needs of the agricultural community with highly relevant, sector-specific functionality. Cloud-based ERP, as an e-agriculture platform, is increasingly important in the effort to turn a profit and feed the world's population.

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. However, it has not been possible to find specific cases of the use of this type of technology and its impact. Maybe one of the reasons is because ERPs are more than just a one-off solution.

4.1.4.2 Blockchain in agrifood value chain

Beginning in the late twentieth century, the ICT revolution enabled creation of global value chains (GVCs). This provided opportunities to access new markets and diversify exports. Instead of learning and establishing an entire production process, suddenly they could specialize in a narrower segment and improve their competitiveness. In addition, participation in GVCs provides exposure to large firms with managerial and technical expertise, allowing for the transfer of knowledge and know-how from advanced to emerging economies as well as among emerging economies (Taglioni & Winkler, 2016).

A promising technology in the area of value chains is known as distributed ledger technology (DLT)[119], in particular blockchain, and its applications in agriculture, for example: (a) agriculture supply chains traceability (Leon, Viskin and Steward, 2018); (b) land registrations; (c) agricultural insurance systems; (d) digital IDs (FAO and ITU, 2019); and (e) food safety and security.

In the area of major companies and large companies, it is possible to highlight some of the following examples:[120]

- The IBM Food Trust initiative started with their collaboration with Walmart China and Tsinghua University. This collaboration has grown into a global consortium that includes companies such as Dole, Driscoll's, Kroger, Nestle, Tyson and Unilever. This data traceability provided by the IBM platform reduced the time it took to trace a mango from the store back to its source from 7 days to 2.2[121]

CASE 12 FARM MANAGEMENT SYSTEM FOR SMART FARMING OPERATIONS

MYCROP

Complete farm and farmer management system

MyCrop is a technology-enabled initiative for farmers, which empowers them through Farmer Mitra (a village-level entrepreneur, VLE) delivering information, expertise and resources, to increase productivity and profitability, hence improving standard of living. This 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 delivery through Farmer Mitras) 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.

Source: www.mycrop.tech

seconds. Such traceability can allow identification of contaminated products and allow for recall before they are consumed.

- Carrefour is a pioneer in this regard and in March 2018 became the first retailer to use blockchain technology for food products, applying it to its Carrefour Quality Line Auvergne chicken. Currently, the technology is rolled out to nine animal and vegetable product lines such as free-range chicken, eggs, cheese, milk, oranges, tomatoes, salmon and ground beef steak. The technology has enabled consumers to have traceability capabilities, with simple smartphone QR scanning consumers are able to download and access a full suite of information about their scanned product; where and how the animal was reared, the name of the farmer, feeds and treatments used, quality standards met, and where the animal was slaughtered. Carrefour would like to have applied this technology to all of its Quality Line food products by 2022.

- Chinese e-commerce Alibaba and JD.com are using blockchain-backed traceability to improve consumer confidence in the authenticity of food products. Beijing-based JD.com started by tracking beef from Kerchin, a company in Inner Mongolia (a province in northern China), to customers in Beijing, Shanghai and Guangzhou. They have also worked with Australian exporter InterAgri and processor HW Greenham & Sons to track Black Angus beef from where it is bred and raised through to processing and transporting.

- The BeefChain[122] was founded by Wyoming cattle ranchers who wanted to know where their beef was being sold. This company received certification from the United States Department of Agriculture (USDA) as a Process Verified Program, and it is the first blockchain company to receive such USDA certification.

- With more than 70 independent farms participating in Honeysuckle's traceable turkey program, Cargill[123], the Minnesota-based agricultural giant owner of Honeysuckle, hopes to establish a stronger connection with consumers. While incorporating a blockchain element to the supply-and-distribution chain means development of a data-rich environment, Cargill's current emphasis in using the technology centres is seen as data warehouses to analyse and support the blockchain technology.

In the case of small farmers, a group of applications have been reported (Kamilaris, Prenafeta Boldú, and Fonts, 2018). Same examples are: (a) AgriLedger uses distributed crypto-ledger to increase trust among small cooperatives in Africa;[124] (b) OlivaCoin is a B2B platform for trade of olive oil, supporting the olive oil market, to reduce overall financial costs, increase transparency and gain easier access to global markets;[125] (c) the Soil Association Certification[126] has launched a pilot technology that tracks the journey of organic food; (d) AgriDigital[127] kicked off a pilot in the Australian grains industry to prove the potential of DLT, partnering with CBH Group, a grain growers' cooperative that handles, markets and processes grain from the Wheatbelt region of Western

Australia to prove the technology had a place in the supply chain; and (e) in January 2018, the World Wildlife Foundation announced a blockchain supply chain traceability project to crack down on illegal tuna fishing.

Overall, blockchain in agriculture and the food supply chain market is projected to grow exponentially stronger at a compound annual growth rate (CAGR) of 47.8 percent to reach US$429.7 million by 2023 from an estimated value of US$60.8 million in 2018.[128] Blockchain has enormous potential to significantly impact the way agricultural business is done, increasing trust between parties, facilitating information sharing throughout the supply chain and significantly reducing agricultural transaction costs (Treat and Brodersen, 2017). According to a reported[129] 2015 study conducted with consumers in South Korea, traceable information translates to more sales and increased brand and product trust.

Blockchain is a promising technology towards a transparent supply chain of food, with many ongoing initiatives in various food products and food-related issues, but many barriers and challenges still exist that hinder its wider popularity among farmers and systems. According to a survey,[130,131] the main barriers are: (a) regulatory uncertainty (48 percent), (b) lack of trust among users (45 percent) and (c) the ability to bring the network together (44 percent). Another report[132] indicates as barriers: (a) processing transactions, blockchain-based systems are comparatively slow, and (b) lack of standards and interoperability between various blockchain platforms.

4.1.5 INTELLIGENT SYSTEMS

Elaboration of intelligent technologies and systems is the main route forward for development of digital agriculture. Intelligent sensors and autonomous robots can essentially perfect the whole control system by increasing preciseness and rational progressing of signals received from the sensory elements. Technological revolution in all the production spheres, especially in computing and research comprising technology equipment will determine application of local (divided intellect) systems in the functioning structures and further development of intelligent systems and technology in agriculture.

4.1.5.1 Deep learning, machine learning and artificial intelligence

Machine learning (ML) is defined as the scientific field that gives machines the ability to learn – from "experience" (training data) – without being strictly programmed to perform a task. ML is being applied in more and more scientific fields. Because of successful applications in various sectors (Kamilaris & Prenafeta-Boldu, 2018), deep learning (DL) has also recently entered the domain of agriculture. One of the applications of DL in agriculture is image recognition, which has overcome many obstacles

CASE 13 BLOCKCHAIN TECHNOLOGIES CONNECTING FARMERS WITH CONSUMERS

WALMART TRACKS ITS LETTUCE FROM FARM TO BLOCKCHAIN

Walmart says it now has a better system for pinpointing which batches of leafy green vegetables might be contaminated. After a two-year pilot project, the retailer announced that it would be using blockchain to keep track of every bag of spinach and head of lettuce. The giant retailer will begin requiring lettuce and spinach suppliers to contribute to a blockchain database that can rapidly pinpoint contamination.

By this time next year, 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. IBM is trying to position itself as a leader in the emerging technology of blockchains. It is competing with established companies like Microsoft and upstarts like Ethereum, which have been developing projects in areas as varied as financial trading and music rights.

The Walmart effort will take time to roll out. In the meantime, it is likely to face questions from critics of the technology, who are sceptical of whether the blockchains being developed by corporations are all that different from old-fashioned online databases.

Source: https://www.nytimes.com/2018/09/24/business/walmart-blockchain-lettuce.html that limit fast development in the robotic and mechanized agroindustry and agriculture (Zuh *et al.*, 2018).

Applications of ML in agricultural production systems can be categorized as:

a) crop management, including applications on yield prediction, disease detection, weed detection crop quality and species recognition;

b) livestock management, including applications on animal welfare and livestock production;

c) water management; and

d) soil management.

ML has been applied in multiple applications for mainly crop management, yield prediction and disease detection (Liakos *et al.*, 2018). However, traditionally the driving intelligence behind AI was the ML method, which determines the decisions that are made by AI technologies and discovers hidden patterns or trends that can be used to make predictions (Pierson, 2017). AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks. Most AI examples that you hear about today – from chess-playing computers to self-driving cars – rely heavily on deep learning and natural language processing. According to the European Commission, AI refers to systems that show intelligent behaviour by analysing their environment and carrying out various tasks – with some degree of autonomy – to achieve specific goals.[133]

Using these technologies, computers can be trained to accomplish specific tasks by processing large amounts of data and recognizing patterns in the data. AI-powered technologies are becoming more pervasive across several industries in the world today, including finance, transport, energy, healthcare and now agriculture. Agro-based firms are looking for new ways to attain and maintain a competitive edge and boost their productivity, as well as to deliver new products and services to the market. Over the last few years, the growth in AI technology 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. This will help farmers to make data-driven decisions. This 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. This gives the farmer time to focus on the big picture of production and expansion rather than spending excess time surveying crops and the state of the farm.

Shifting weather patterns including an increase in temperature, rapid changes in rain patterns and levels, and groundwater density can affect farmers, especially those who cultivate unirrigated lands and depend a lot on rains for their crops. Leveraging the cloud technology and AI to issue advisories for sowing as well as predict pest control and commodity pricing is a major move towards creating increased income for the farming community. The potential source of weather-related data will continue to

CASE 14 USE OF AI FOR WEATHER FORECAST AT GLOBAL LEVEL

IBM THE WEATHER COMPANY

Deep weather data and insights help make better, faster decisions

The Weather Company, an IBM Business, delivers personalized, actionable insights to consumers and businesses across the globe by combining the world's most accurate weather data with industry-leading AI, Internet of Things (IoT) and analytics technologies.

Their solutions provide newscasters, pilots, energy traders, insurance agents, state employees, retail managers, farmers and more with insight into weather's impact on their businesses, helping them make smarter decisions to improve safety, reduce costs and drive revenue.

The model can deliver damage predictions that are 70–80 percent accurate 72 hours before the storm is expected. This gives utilities enough time to arrange to have enough crews to repair the downed lines after the storm has passed through.

Source: www.ibm.com/weather

grow dramatically and new advances in ML are making it possible for government agencies and companies to make better use of all these data. Weather forecasting can never be truly perfect, but AI will allow the practice to continue to improve in its accuracy and in its resolution. Improving and hyper-localizing weather forecasts enables numerous sectors to squeeze out extra efficiency a small reduction in irrigation in part of a field.

Creating a pest attack prediction model again leverages AI and ML to indicate in advance the risk of pest attack. Common pest attacks, such as jassids, thrips, whitefly and aphids, can pose serious damage to crops and impact crop yield. To enable farmers to take preventive action, guidance on the probability of pest attacks would be helpful. Farmers will get predictive insights on the possibility of pest infestation, which will help them to plan, adopt pre-emptive measures and reduce crop loss caused by pests. All this will certainly contribute to double the farm income. The measure to indicate the risk of pest attacks based on weather conditions and crop stage in addition to the sowing advisories is a help long overdue.

By including data, for example, climate conditions, kind of soil, commercial centres, potential invasions and information in the algorithm, AI can help farmers to decide on the best seed to use to maximize production. In times of water shortage, using AI-powered farming will help save water. It uses solar energy to function, so is also pollution-free. Intelligent agriculture maximizes return on investment, making it an economically smart choice. This can improve the ROI for all farms. Further, AI innovation can process investigations that help farmers minimize losses in the production supply chain of their farms.

AI is well on the road to completing tasks typically done manually by researchers, from identifying individual animals from photos for population studies to categorizing the many millions of camera trap photos gathered by field scientists. The use of AI has been of enormous economic benefit for livestock farmers in many countries through improvement of their stock. Affordable tools with the ability to continuously monitor the growth rate of livestock animals are highly sought after by the livestock industries. This demand is driven by the potential for these tools to assist in improving animal welfare and production efficiency.

Another exciting development in terms of image recognition in AI is Google's work to train AI to recognize 5000 species of plants and animals, which would improve drone ability to detect pest disease and crop damage. This advancement is huge, as it would allow farmers to monitor their acreage far more quickly and accurately than they ever have before, and to understand pest patterns over time.

CASE 15 YIELD MANAGEMENT USING AI IN RURAL INDIA

MICROSOFT CORPORATION AND CORTANA INTELLIGENCE SUITE

Yield management using AI

The emergence of futuristic techs such as artificial intelligence (AI), cloud machine learning (ML), satellite imaging and advanced analytics, are helping to develop an ecosystem for smart, efficient and sustainable farming. Fusion of these technologies is enabling farmers to achieve higher average yield per ha and better control over the price of food grains, ensuring they remain in profit.

At present in India, in the state of Andhra Pradesh, the Microsoft Corporation is working with farmers rendering farm advisory services using Cortana Intelligence Suite including ML and Power BI, to enable transformation of the data into intelligent actions. This pilot project makes use of an AI-based sowing application which recommends sowing date, preparation of cultivable land, fertigation based on soil analysis, FYM requirement and application, seed treatment and selection, and optimization of sowing depth suggestions to farmers, and has resulted in a 30 percent increase in the average crop yield per ha.

AI models can also be employed in recognizing optimal sowing period in various seasons, statistical climatic data, real time moisture adequacy data (MAI) from daily rainfall statistics and soil moisture to construct forecast charts and also gather inputs on best sowing time for farmers.

Forecasting potential pest attacks, Microsoft in collaboration with United Phosphorus Limited is developing a Pest Risk Prediction Application Programming Interface (API) that has a strategic advantage of AI and ML to signal in advance the potential chances of pest attack. Grounded on the weather conditions, growth stage of the crop in field, pest attacks are forecast as high, medium or low.

Source: https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/

CASE 16 AI AGRICULTURE INTELLIGENCE PLATFORM FOR CROP MONITORING

TARANIS IS AN AI-POWERED AGRICULTURE INTELLIGENCE PLATFORM

This company was selected to be part of John Deere's start-up collaborator. It uses sophisticated computer vision, data science and deep learning algorithms to enable farmers to make informed decisions. Taranis is an international precision ag-tech start-up that offers a full stack solution for high precision aerial surveillance imagery to pre-emptively avert crop yield loss caused by insects, crop disease, weeds and nutrient deficiencies.

Introducing the world's first "air scouting" capability the Taranis platform helps service providers, land managers and producers monitor their fields, make informed decisions and then act on them.
Taranis combines field imagery at three different levels from satellite images, through plane imagery to drone leaf level imagery, and is using AI deep learning technology to recognize crop health issues. It helps monitor each field throughout its life cycle leveraging combinations of different imagery sources and analytics based on growth stage.

The platform is capable of monitoring fields and finding early symptoms of uneven emergence, weeds, nutrient deficiencies, disease or insect infestations, water damage and equipment issues. Overseeing millions of acres of farmland in the United States, Argentina, Ukraine, Brazil and Russia, the company employs over 75 people worldwide and is headquartered in Tel Aviv with subsidiaries in Argentina, Brazil and the United States.

Source: http://www.taranis.ag/

The artificially intelligent machines can also carry out aeroponics. The technique is widely used in vertical farming. The plant, through aeroponics gets exposed to soil water 99.98 percent of the time, but for the remaining 0.02 percent of the time, it is exposed to a solution (water + plant decompose) that is rich in micronutrients and minerals. This adds to the fertility of the plant and at the same time decreases the water and nutrient requirements of the plant by 40 percent and 30 percent, respectively.[134]

For the team behind the CGIAR platform for Big Data in agriculture, farming is the next frontier for using AI to efficiently solve complex problems. The team which

CASE 17 AI FOR FARM-TO-FORK ON PIG PRODUCTION IN CHINA

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

Monitoring pig farms in real time

China's big tech giants of Alibaba Group Holding and JD.Com have lined up to have their piece of the smartening agricultural technology pie.

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 farming growing enterprises in China. The programme will also be 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.

Beijing's JD.Com has also launched a facial recognition system, designed for swine. The three modules of Shennong Brain, Shennong Internet of Things Devices and the Shennong System, help monitor each pig's weight, growth and health status.

JD.Com's system 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.

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

includes biologists, agronomists, nutritionists and policy analysts working with data scientists is using Big Data tools to create AI systems that can predict the potential outcomes of future scenarios for farmers. By leveraging massive amounts of data and using innovative computational analysis, the CGIAR platform is working to help farmers increase their efficiency and reduce the risks that are inherent in farming. The idea behind the CGIAR platform is to first create a better way for researchers to manage and share agricultural data.[135]

Silicon Valley is also using AI to impact agriculture, but these companies tend to focus more on the technological aspect than on the agricultural aspect (Shoham, *et al.* 2018). These technologies include innovations such as indoor farms and robotic harvesters, equipment that requires significant investment and resources.

Although AI presents immense opportunities in agriculture application, there still prevails a deficiency in familiarity with advanced high-tech ML solutions in farms around the world. Exposing farming to external factors like weather conditions, soil conditions and vulnerability to the attack of pests is high. A crop raising plan scheduled at the start of the season might not seem to be good at the start of harvesting as it gets influenced by external parameters. AI systems require many data to train machines to take precise forecasting or predictions. In the case of a very large area of agricultural land, spatial data could be collected easily while getting temporal data is a challenge. The various crop-specific data could be obtained only once in a year when the crops are grown. As the database takes time to mature, it involves a substantial amount of time to construct a robust AI machine learning model. This is a major reason for use of AI in agronomic products like seeds, fertilizer and pesticides rather than in field precision solutions.

In conclusion, the future of farming is largely reliant on adapting cognitive solutions. Although there is vast ongoing research and many applications are already available, the farming industry remains underserved. While it comes down in dealing with realistic challenges and demands faced by the farmers, using AI decision-making systems and predictive solutions in solving them, farming with AI is only at a nascent stage (Dharmaraj and Vijayanand, 2018). The European Union has recently released ethics guidelines for trustworthy AI,[136] which put forward a set of seven key requirements that AI systems should meet to be deemed trustworthy.

4.1.5.2 Robotics and autonomous systems

Artificial intelligence, field sensors and data analytics are some of the advanced systems used in that endeavour, but the one area in which these technologies converge is robotics and automated equipment. Agricultural robots, sometimes known as "agrobots", are seen as an upcoming technology that will deeply influence

agriculture in the future. From nursery planting to shepherding and herding, robots are already in agriculture. Autonomous, robotic vehicles have been developed for farming purposes, such as mechanical weeding, crop monitoring, fertilizer application or fruit harvesting. Advanced robotic systems will also take care of and harvest plants, as well as carry out on-farm data collection, increasing crop yields. Several robots that can carry out some of these operations are already available, while many others will hit the market soon.

There are now a number of crop weeding robots that reduce the need for herbicides by deploying camera-guided hoes (Tillett *et al.*, 2008), precision sprayers (Binch & Fox, 2017) or lasers (Mathiassen *et al.*, 2006) to manage weeds.

In general there are two types of agrobots: one category which is specialized in tasks with the support of different types of sensors, for example weeding, harrowing, herbicide/pesticide application, crop monitoring or harvesting. The second category includes autonomous platforms able to do different works depending on the application attached to them (similar concept to a tractor). These platforms can sow, weed or harvest crops just by changing the application and are able to work in swarms, reducing the need of labour force.

Therefore, at the farm level, robotic systems are now commonly deployed for milking animals.[137] The take-up is a relatively small percentage at the moment, but an EU foresight study predicts that around 50 percent of all European herds will be milked by robots by 2025 (European Parliament, 2016).

Robotic systems are starting to perform tasks around the farm, such as removing waste from animal cubicle pens, carrying and moving feedstuffs, etc. Systems are in use and under development for autonomously monitoring livestock and collecting field data, all commercially useful for efficient and productive livestock farming. There are

CASE 18 ROBOT FOR AGRICULTURE AND VITICULTURE

DINO ROBOT BY NAIO TECHNOLOGIES

The Dino robot is designed to make vegetable weeding on large-scale vegetable farms easier. Its main asset is that it works autonomously, so you have more time for tasks with higher added value.

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 an eco-friendly robot that weeds crops mechanically with a range of specific tools. The robot is 100% electric and helps to reduce the use of weed-killers while simultaneously lowering the carbon footprint.

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.

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

further opportunities to apply more advanced sensor technologies, combined with more autonomous systems, to perform tasks on the farm.

There is another alternative for automated equipment technology, which is transformation of current equipment into automated equipment. There are good examples of normal tractors and other motorized equipment being equipped with guidance and sensing systems that allow them to work autonomously and in swarm. This opens up a big opportunity for farmers to evolve towards more efficient production systems without investing in brand new equipment, and being able to operate their machinery, reducing the costs of adaptation and capacity building.

Agrobots also provide a big opportunity for the agritech sector in developing countries. The versatility of the equipment, which can be designed to do simple farm works such as weeding or transport of goods, increasing farm productivity and reducing drudgery is associated with the development of new job opportunities for qualified youth who may find a niche to work in technological solutions applied to their country context. This combined with the need for specialized operators and technicians to keep agrobots functional, presents a new business and employment field for youth in developing countries.

Field robots are already being deployed to help farmers measure, map and optimize water and irrigation use. Likewise, robots that use precision technologies to apply fertilizers and pesticides within agricultural systems will reduce environmental impacts. 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. In addition, novel sensors deployed on robots can reduce pesticide use by both detecting pests and diseases and precisely targeting the application of insecticides and fungicides. Robots could also be deployed as part of integrated pest management systems, for example, for the accurate and low-cost dispersal of biopesticides to counteract crop pests and diseases.

The increase in the precision of the operations and the lower impact on the soil and reduction in the use of inputs present some environmental advantages of adoption of agrobots. , inputs; and cover manpower shortage at peak seasons such as harvest time for special crops. They can also enable

However, there are some constraints to its adoption, and farming systems as well as value chains would need to go through a transformation process to allow successful digitalization incorporating robots and autonomous equipment. Capacity, access to digital infrastructure and technical support are some of the main hurdles to be overcome if farmers are to enjoy the benefits of this technology.

Technology adoption is likely to occur in measured steps. Most farmers and food producers will need technologies that can be introduced gradually, alongside and within their existing production systems. Thus, for the foreseeable future, humans and robots will frequently operate collaboratively to perform tasks, and that collaboration must be safe. There will be a transition period in which humans and robots work together as first simple and then more complex parts of work are conducted by robots, driving productivity and enabling human jobs to move up the value chain.

CASE 19 ROBOTS PICKING STRAWBERRIES ON US FARMS

HARVEST CROO ROBOTICS

Crop harvesting

Harvest CROO Robotics has developed a robot to help strawberry farmers pick and pack their crops. Lack of labourers has reportedly led to millions of dollars of revenue losses in key farming regions such as California and Arizona. An estimated 40 percent of annual farm costs are funnelled into “wages, salaries and contract labour expenses” for crops such as fruits and vegetables where labour needs tend to be the highest.

Harvest CROO Robotics claims that its robot can harvest 8 acres in a single day and replace 30 human labourers.

In June 2017, Florida-based Wish Farms announced its implementation of Harvest CROO Robotics’ strawberry harvester in the summer of 2017. The farm claims that the robot spans “over six beds of plants” and carries “16 individual picking robots”.

Source: https://harvestcroo.com/

CASE 20 HANDS FREE HECTARE

Hands Free Hectare is a project started by the Harper Adams University in UK, where with the use of open source technology they transformed old agricultural equipment into automated equipment able to prepare the land, sow, tend and harvest 1 ha land of cereal crop without the intervention of a human inside the perimeter of that hectare.

They are using small-scale machinery that is already available on the market, and adapting the machinery in the university's engineering labs ready for the autonomous field work.

This project is currently in its third year; it is receiving funds for scale-up, and has successfully done two harvests of barley.

Source: http://www.handsfreehectare.com/

4.2 Logistic

Access and use of data along the value chain can increase the transparency, efficiency and resilience of the food value chain – for instance, through traceability, assisting in certification of standards and by facilitating trade logistics chains and border processing. There is a growing demand for traceability and transparency throughout the chain by public authorities for the purposes of monitoring food safety. There is also a growing demand from the private sector, particularly food processors, looking to improve their planning and logistics, support tracing and tracking, and to prove compliance with sustainability requirements at the retail level in line with consumer preferences. Delivering transparency and traceability require managing increasingly large amounts of data passed through and used by a large number of economic actors.

Reviewing the recent literature on the impact of ICT in the rural sector in developing countries, Deichmann, Goyal and Mishra (2016) conclude that digital technologies overcome information problems that hinder market access for many small-scale farmers, increase knowledge through new ways of providing extension services, and provide novel ways for improving agricultural supply chain management (AGRA, 2017). Aker's work (2011) on small-scale African farmers showed significant time and cost savings in using information and communication technology (ICT). At the other end of the productivity spectrum, modern large-scale agriculture is becoming unthinkable without such precision agriculture tools as GPS, satellite and drone monitoring, and increasingly detailed and instantly available weather and climate information (Oliver *et al.*, 2010). Two main difficulties exist in analysis of the impact of ICTs on agricultural development. First, ICTs affect a wide array of outcomes in addition to agriculture; because ICTs enhance economic opportunities in a wide variety of ways, they also have sizeable macroeconomic impacts (Gruber and Koutroumpis, 2011). Second, ICTs encompass many different types of technologies, from computers and the Internet to radio and television to mobile phones, to name just a few. Thus, the impact of ICTs varies widely depending on which specific technology is used (Nakasone *et al.*, 2014). However, some constraints remain; access to (efficient) transport and trade infrastructure still matters for accessing quality inputs and export markets, particularly for perishable products.

Americans are incorporating a wide range of digital tools and platforms into their purchasing decisions and buying habits, according to a Pew Research Center survey of US adults. The survey found that roughly 8 in 10 Americans are now online shoppers: 79 percent have made an online purchase of any type, while 51 percent have bought something using a cellphone and 15 percent have made purchases by following a link from social media sites.[138] GSMA has estimated that as much as 85 percent of ecommerce transactions in Africa are "payment on delivery", a sign of a low-trust environment in which the buyer will only part with payment on evidence of delivery.[139] This clearly adds to costs and risks for buyers and sellers, apart from making it hard for the platform to take its fee.

Although digital commerce is at an early stage in Africa, its reach is already widening. Research by FIBR, a programme of BFA with the support of the Mastercard Foundation, shows that African MSMEs are already moving online. Micro-entrepreneurs perceive the online marketplace as something that far exceeds anything that would be available in the offline world, and they are already using social media platforms particularly WhatsApp, Facebook, and Instagram, which are not specifically designed for digital commerce to promote their services. Similarly, ordering on Chinese e-commerce platforms such as AliExpress is rapidly growing among customers and online sellers. The ubiquitous nature of mobile money in some countries in Africa has made remote transactions possible (Mastercard Foundation, 2019). In 2017, the Chinese overall e-commerce market ranked first in the world in

CASE 21 DIGITAL PLATFORMS FOR CONNECTING SMALLHOLDER FARMERS WITH THE MARKET IN INDIA

PLATFORMS FOR THE COORDINATION OF SMALLHOLDERS

Connecting smallholders to commodity trading: e-choupal in India

e-Choupal is an initiative by the Imperial Tobacco Company of India (ITC) Limited, one of the country's largest agricultural exporters, to link directly with rural farmers via the Internet for procurement of agricultural and aquaculture products such as soybeans, wheat, coffee and prawns.

The e-Choupal model was developed to tackle the challenges posed by fragmented farms, weak infrastructure and numerous intermediaries. The programme sets up Internet access kiosks in rural India to provide farmers with access to marketing and agricultural information, which helps them to make better-informed decisions and potentially increase their income by better aligning farm output to market demand.

The programme brings connectivity infrastructure and a portal to farmers. The computer of a "focal point farmer" with Internet connection serves on average 10 villages and reaches 600 farmers. A portal echoupal.com provides access to dedicated services: information on farming best practices, market prices, weather forecasts, news and an interactive Q&A section with ITC's agricultural experts. ITC is also partnering with banks to offer farmers access to credit, insurance and other services, and it has built a network of warehouses near production centres to provide inputs to farmers and test output at the individual farm level. Access to information by farmers has helped improve both farming practices and the quality of products and to solutions to create supply chain efficiencies, linking farmers to commercial markets while facilitating productivity improvements. A working example is the Connected Farmer Alliance (CFA).

The CFA is a publicprivate partnership between the US Agency for International Development (USAID), Vodafone and TechnoServe. Its objective is to support commercial viability of mobile solutions for smallholder farmers to help farmers work with agribusinesses and better manage their own crops and finances. CFA uses Vodafone's M-Pesa mobile money solution to enable agribusinesses to transact with farmers for payments and loans. It allows the agribusiness to better manage their farmer data, drive business analytics, and develop deeper relationships with farmers through the sharing of information.

Sources: http://www.itcportal.com/businesses/agri-business/e-choupal.aspx
http://www.technoserve.org

both sales and growth, far outpacing the United States, the world's second-largest e-commerce market (ADB, 2018).

Rapid economic growth and good infrastructure have fuelled the growing volumes of digital commerce, although these factors may be a result as well as a cause of the growth of digital commerce. Moreover, in China digital commerce is closing the urbanrural digital divide, as evidenced by "Taobao" villages (enterprise zones) and rural Taobao strategies. However, government-supported efforts to stimulate digital commerce in rural areas have mostly had a positive effect on rural consumption rather than employment (Couture *et al.*, 2018). In China, e-commerce, the online retail revenue reached CNY 9.0 trillion (US$1.3 trillion) with a YOY 23.9 percent. The revenue generated from sub-area (rural areas, towns, and villages) e-commerce increased to CNY 1.4 trillion with a YOY 30.7 percent.[140]

Rural business owners who export said that e-commerce plays a big role, with 80 percent using digital tools and services to trade goods and services abroad. The top export destinations for rural businesses are the EU (84 percent) followed by the United States (45 percent). In addition, 43 percent of all rural businesses specifically sell online through their own site or via a third-party site, with the top two sectors using e-commerce being retail (80 percent) and the accommodation and food sector (71 percent).[141]

Even in developed countries, rural communities are facing constraints. Some 67 percent of US farms had access to the Internet in 2013, only 16 percent reported purchasing agricultural inputs and 14 percent reported conducting marketing activities (sales, auctions, commodity price tracking and online market advisory services) over Internet. In the UK, where about 94 percent of farms have access to Internet, only about 46 percent of these farms report using the Internet to purchase or sell materials for the farm, and 87 percent state they use Internet/Computer for submitting forms or banking.[142]

CASE 22 E-COMMERCE FOR POVERTY ALLEVIATION IN RURAL CHINA (TAOBAO VILLAGES)

China's rapid development of e-commerce has begun to reshape production and consumption patterns as well as change people's daily lives. In 2014, the Alibaba Group, in collaboration with the government, launched the Rural Taobao Programme to help give rural residents greater access to a broader variety of goods and services and help farmers earn more by selling agricultural products directly to urban consumers in online platforms. The programme has four main activities:

1) Setting up an e-commerce service network in counties and villages;
2) Improving logistical connections for villages through "two-stage delivery" shipping packages from county centres to villages;
3) Providing training in e-commerce and promoting entrepreneurship; and
4) Developing rural financial services through the AntFinancial subsidiary of Alibaba.

The Rural Taobao Programme has expanded rapidly, from 212 villages in 12 counties in 2014 to more than 30 000 villages in 1000 counties in 2018, spreading from the coast to inland. While over 95 percent of the Taobao Villages cluster in the eastern region, particularly in Zhejiang, Guangdong, and Jiangsu, they have started to spread to the inland region, going from four shops in 2014 to over 100 in 2018.

The formation of Taobao Villages broadly proceeded through three stages:

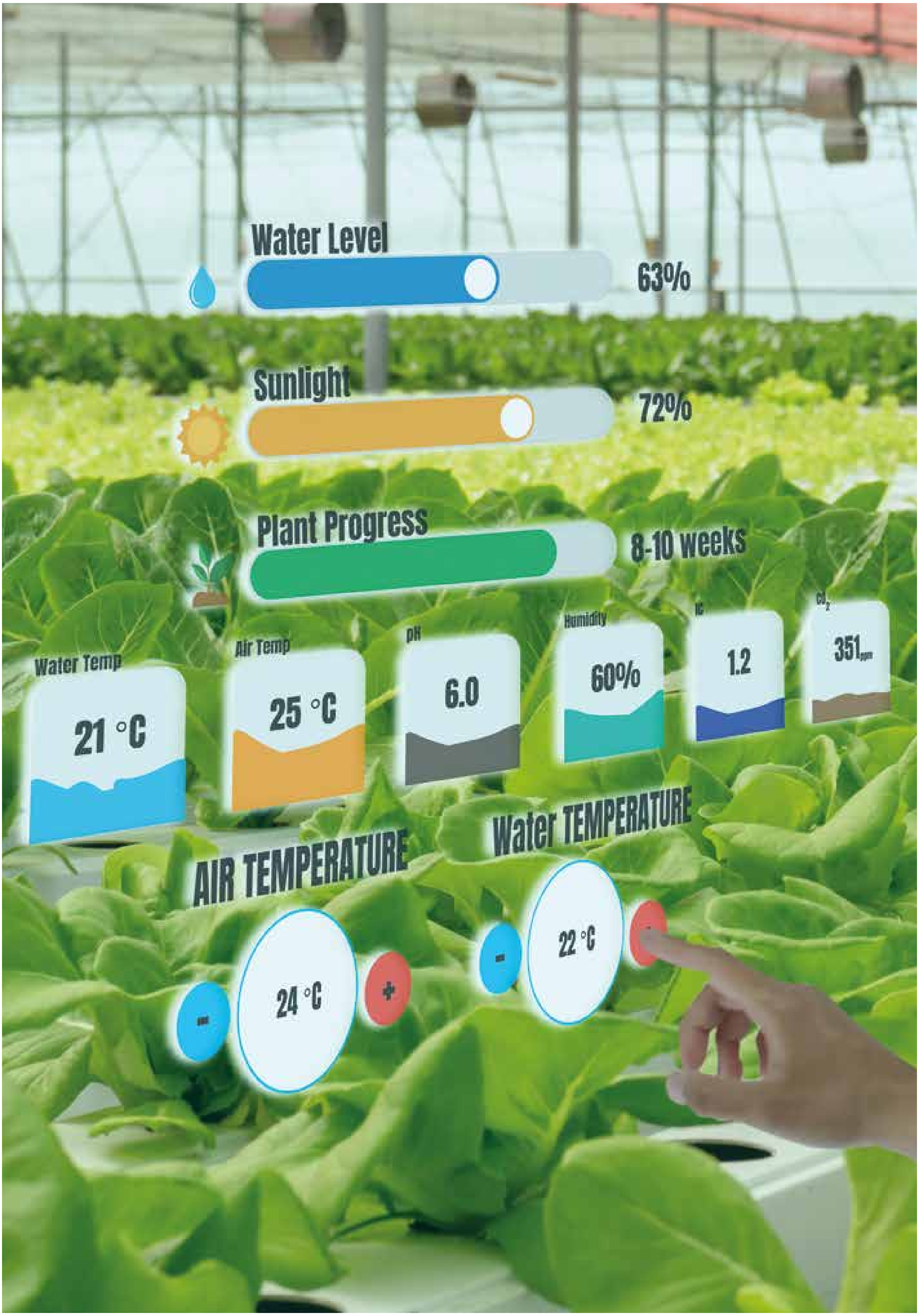
1) Version 1.0 was mainly about grassroots development: Villagers, often returned migrants with distinct entrepreneurial skills, led the establishment of online businesses and created models for other villagers to follow. Examples include the early Taobao Villages, such as Shaji in Jiangsu province.
2) As e-commerce developed and more Taobao Villages prospered, version 2.0 was accompanied by government support: Local governments provided direct support for infrastructure, e-commerce training, and finance. Examples include Jieyang in Guangdong province.
3) In recent years, as more Taobao Villages formed, the platform-ecosystem version 3.0 has emerged: Local governments are providing support through subsidies for specialized e-commerce service providers and firms to build an e-commerce ecosystem with e-platform companies. Tailored support to villagers includes training and developing suitable local online products and branding. This process is typical of Taobao Villages in locations where the industrial base is weak and human capital (entrepreneurship and skills) more limited. Examples include Xifeng in Guizhou province.

Its main activities consist of establishing and improving rural e-commerce public service, fostering rural e-commerce supply chains, promoting connectivity between agriculture and commerce, and enhancing e-commerce training. The programme grew quickly and by 2018 had supported 1016 demonstration counties, covering 737 poverty-stricken counties (89 percent of the total), including 137 counties with extreme poverty (41 percent of the total). The share of poverty-stricken counties among demonstration counties increased from 27 percent in 2014 to 45 percent in 2015 and 65 percent in 2016, while in 2017 and 2018, more than 90 percent were poverty-stricken counties, with the rest underdeveloped.

While further research is needed to clarify and quantify the relationship between e-commerce participation and household welfare improvement, numerous anecdotal cases show that people gain wealth and have better lives after participating in e-commerce. Women in particular seem to benefit and account for a large share of e-commerce entrepreneurs. The ratio of women to men entrepreneurs in e-commerce is at or near parity, compared to a ratio of 1:3 in traditional businesses. The average age of female entrepreneurs in traditional businesses is 47.6 while the online counterparts tend to be younger, with those aged 25–29 accounting for 30 percent and those aged 18–24 nearly 30 percent on the Taobao platform. The average age of online female entrepreneurs is 31.4.

Success stories in Taobao Villages suggest that digital technologies can contribute to inclusive growth in rural China. They can lower the required skill threshold allowing individuals, including the less educated, to participate in e-commerce and earn more. The experience in Taobao Villages has sparked strong interest among researchers, policy-makers and the private sector to explore the use of e-commerce as a tool for poverty alleviation and rural vitalization.

Source: http://www.aliresearch.com/en/news/detail/id/21763.html



Water Level
63%
Sunlight
72%
Plant Progress
8-10 weeks
Water Temp
21 °C
Air Temp
25 °C
pH
6.0
Humidity
60%
1.2
351
AIR TEMPERATURE
24 °C
Water TEMPERATURE
22 °C

5 CONCLUSION AND FUTURE WORK

With the digital transformation ongoing, the agriculture environment is constantly evolving and may ultimately transmute into digital and smart agriculture. Understanding the major changes, we will be able to identify gaps, risk and opportunities and how they are driving new business models, adopting technologies and finally changing the economic, social and environmental elements in the digital age. Today, we see a booming agriculture that is advancing by leaps and bounds in the process of digital transformation, but at the same time we see how small farmers are not included in this transforming process, increasing the digital divide, not only from the point of view access or e-literacy, but even more worryingly, from the point of view of production and economic and social integration.

This report aims to identify the different scenarios in which the process of digital transformation is taking place in agriculture. This identifies those aspects of basic conditions, such as infrastructure and networks, affordability, education and institutional support. In addition, enablers are identified, the factors that allow adoption and integration of changes in the production and decision-making processes. Finally, we identify using cases, existing literature and reports how substantive changes are taking place in adoption of digital technologies in agriculture.

One of the first conclusions is related to the lack of systematic and official data regarding rural areas and digital technologies in agriculture. Considering the work carried out, there are only data at the country level, without a greater distinction in rural and urban areas, which complicates a potential vision and baseline of the situation existing in rural areas. Most of these data correspond to variables of connectivity and coverage of telecommunications services (network, Internet and mobile services), without reporting the quality of them and/or the affordability from the different groups. It is important to note that the meaning of urban areas (Dijkstra, *et al.* 2018)[143] is not clear or at least has many understandings, and therefore, we need greater clarity for future measurements and data collection. In terms of education or e-literacy, the information is also at the level of country, in some cases disaggregated by age groups, and based on formal education without minor information related with digital education. Finally, in terms of the institutional support or regulatory framework, the situation is even worse, this element was proxy about government services availability or connectivity regulations, and some data protection legislation. This situation creates a strong disadvantage and difficulty in being able to understand the true situation in rural areas, and with it in agriculture, to determine in an effective way a precise assessment.

A second conclusion relates to the difference between developed and developing countries, together with the existence of global companies versus those of a local, community or family nature. Land size, cost and financial access are some of the economic factors that determine the rate of agricultural technology adoption. Farmers' education level, age, social groupings, and gender are some of the social factors that influence the probability of a farmer to adopt modern agricultural technologies. These factors promote adoption of digital technologies by major farmers, usually associated with multinational companies, to the detriment of small farmers, who must face additional problems of access to the infrastructure of communications (networks) and technology in general.

Finally, a third general conclusion relates to the digital technologies themselves. These technologies have strong economies of scale and scope, making a greater volume required to make them profitable, but at the same time the capacity for integration with other technologies generates positive effects. Again, this phenomenon promotes the largest scale and/or scope, generating greater concentration and size of those companies that can adopt and operate these digital technologies in a sustainable manner, generating important entry barriers. It is in this sense that small farmers face a disadvantage in adoption and use of these new technologies, generating again perverse incentives with respect to small farmers and less developed countries. From the cases and backgrounds studied, digital technologies clearly deliver economic value, as long as they reach the scales and necessary scope, making more than its adoption the main objective, the economic sustainability becomes relevant. Of course, there is also room for those digital technologies promoted by governments, associations of farmers or organizations, but they must necessarily achieve economies of scope, developing solutions that integrate a series of services.

The challenge is that transformative innovations and modern tools for making agricultural systems more efficient and sustainable, such as precision agriculture, are often not designed for smallholder use. Adaptation to smaller scales is a major challenge for smallholder farmers in developing countries. Below we analyse the different levels identified in the incorporation, adoption and profitability (impact) of digital technologies in agriculture.

5.1 Boosting enablers to connect marginalized and remote communities

A well-developed digital infrastructure, especially in rural areas, is a precondition for digital agriculture. While the digital divide is a very significant problem in developing economies, recent data show that people around the world have much better access to ICTs than they did years ago, with the largest improvements in middle-income countries. This has been possible with advances in technology and regulatory reform. However, just as the connectivity for a certain technology (e.g. dial-up Internet access) improves across income levels, a new technology (e.g. broadband) appears – leaving users in developing economies continually "playing catch-up".

Mobile-cellar subscriptions in the last five years was driven by countries in Asia and the Pacific region, and Africa. Growth was minor in the Americas and the former Soviet republics, while a decline was observed in Europe and the Arab States. However, many people still do not own or use a mobile phone. Nevertheless, increased mobile subscription does not mean equal distribution among population based on rural/urban or gender and youth. In fact, there are unbalanced wide disparities. Even nowadays, 4G overtook 2G to become the leading mobile technology across the world, with 3.4 billion connections accounting for 43 percent of the total, and coverage possibility for those living in rural areas remains limited, especially those in LDCs, where only around a third of the rural populations are covered by 3G networks.

There is still a wide disparity on literacy at global level and between regions. At the turn of the twenty-first century, more than half of the population in poor countries remains illiterate. In countries in which most of population lives in rural areas, those engaged in the agriculture activities are often more illiterate, emphasizing the LDCs. However, developing countries are not exempt from this situation, where the gap between rural and urban literacy is noted. Also, those regions and LDCs that have higher gap in youth literacy between urban and rural areas show a higher gender gap in the youth population.

Youth unemployment stands at a much higher level than the average unemployment rate for the general population, and in many cases, it is more than twice as high, especially emphasized in rural areas. Literacy, level of education and unemployment are correlated in rural areas. In addition, this correlation is stronger in LDCs and those developing countries in which IT infrastructure is lower than the world average. To reduce this unbalance on labour supply and demand in the future, digital technologies will be crucial. In the digital transformation process it is obvious that as a minimum, employers will want future employees who are adept at using technology to connect, communicate and collaborate with workplace technology. However, continuing lags in smallholder agricultural productivity and unprecedented population growth have intensified concerns on whether the current youth generation will increasingly seek employment opportunities outside the agriculture and food sector.

To unlock the full potential of digital agriculture transformation, governments need to create a regulatory environment and promote policy incentives to enable the digital agriculture ecosystem. Not all countries have achieved success in the digitalization process, because designing and managing a digital government programme requires a high level of administrative capacity. Developing countries, most in need of digital government are also those with the least capacity to manage the process. In this endeavour, just as the digital divide must be made a policy priority by making the business case for it, digital inclusion must also be made a policy priority by explaining the socio-economic benefits to smallholder farmers. So, effective strategies for addressing the problem of e-agriculture in developing countries and closing the gap with developed countries, must combine IT infrastructure with social, organizational and policy change. By engaging the private sector, governments can make companies and start-ups their partners in a full-potential digital agriculture strategy. At the same time, they must engage farmers and other stakeholders in the agrifood sector alike to define the social, economic and environmental values from those services.

The increased interest in data-enabled farming and related services is also blurring the boundaries between agricultural-supply sectors such as seeds, crop protection, fertilizers, equipment and distribution. New entrants from the technology industry as well as nimble start-ups are already looking to change the competitive landscape, although no clear winner is likely to emerge in the near future. In fact, the vast data collection drives the evolution of a new scientific realm, governed by machine learning and AI. New models that have never existed before must be developed to make the data useful and actionable. Yet the information gathered is often insufficient to fully inform the comprehensive solutions and partnerships needed to transform smallholder farming into viable, sustainable businesses. All countries must take a standpoint because certain manufacturers collect the data in their devices and have the opportunity to exploit them. Farmers are fully aware of the issue and are reluctant to share their data without receiving something in return. That said, effective use of the data necessitates a degree of massification, and therefore sharing.

5.2 Drivers and demands for unlocking digital agriculture transformation

People living in developing countries have less access to Internet connectivity, therefore people living in these regions have a generally low literacy rate, but also, they lack basic digital skills. Access to the Internet remains the most critical component for unlocking the possibilities of new technologies. The goal of universal Internet access remains an issue. Unequal access to mobile technology/Internet is embedded in the structural gender gap and threatens to exacerbate the inequalities women already experience. For example, development of mobile technology has played an important role in shaping the impact of social media. Across the globe, mobile devices dominate in terms of total minutes spent online. This puts the means to connect anywhere, at any time, on any device in everyone's hands. However, farmers are still marginalized. Despite the global rapid increase of Internet and mobile phones and device usage in rural and remote areas, there has not been much data, research and studies on the usage of mobile Internet and social media in rural communities.

Mobile phones, especially smartphones, are a game changer in the agrifood sector in LDCs and developing countries. Price decreases of mobiles and Internet and growth of youth population brings mobiles close to the farms and brings closer open opportunities for services and information to be delivered through mobile apps, videos and social media. Indeed, sites such as Facebook, Twitter, YouTube and others are a cost-effective means of spreading the word and getting support among smallholder farms. In addition to farmers, other key agricultural stakeholders, such as extension officers, agrodealers, retailers, agricultural researchers and policy-makers are promising clients. Nevertheless, not all farmers adopt ICTs in a quick manner, still there are constraints to be overcome. One factor is the content of the information shared through ICTs. If new technologies, however exciting, do not provide the type of information that farmers actually need, they will not be adopted. For information to influence farmers' production and marketing decisions, it must be properly targeted. Such issues are facing women, but devices and applications designed by men tend to be less responsive to women's priorities and needs, and in some cases, can actually discourage women from using them or even raise safety issues. Another factor is the early age of ICT adoption in the agriculture sector. However, many lack the necessary understanding of ICTs to request or employ ICT services. This is also because ICT applications in the agrifood sector are still relatively new, even in more advanced economies, and many e-services are still being developed.

Regarding the main constraints faced by in adoption of advanced digital technologies; the lack of standards and the limitations on the exchange of data between systems prevents adoption of machinery and instrumentation from different brands and companies. In addition, those farmers eager to adopt technologies that are more advanced lacks independent advisory/consultancy services to help make decisions on the investments required. Most of farmers and extension officers do not possess digital skills, thus raising the fear of adoption and usage of precision agriculture technologies. Digital skills are a concern in both developed and developing countries. It is obvious that those countries having introduced ICT within the education process have higher e-literacy and accessible and affordable digital tools and Internet, will have better performance on digital skills. However, rural areas lag behind in the process of gaining those skills.

Digital technology is redesigning the dynamics of the agrifood sector. However, the lack of an overview, a lack of clarity on the part of operators on how to exploit the opportunities of digital agriculture, the poor perception of the need for innovation and the lack of a systematic approach to the digitalization of processes, are still unresolved issues. Digital farming requires the collaboration of all players in the agricultural value chain to leverage its full potential. In a world where so many people have access to education and cheap tools of innovation, the spot for innovation today is moving closer to the farmers because all the farmers together are smarter than any one alone and all the farmers have to tools to invest and collaborate.

Youth are coming to agriculture with specific university degrees and specializations. It is about science and technology. It is a new generation that is comfortable with innovation and loves to experiment. However, to meet their demands, both public and private sectors must act and enable an environment and sustainable digital ecosystem for retaining and generating digital talents for the agriculture and food sector. Youth engaged in the agrifood sector have become more entrepreneurship-oriented and have learned to take calculated risks to open enterprises. Also, the number of small-scale farmers having many of the qualities of an entrepreneur is increasing. Yet insufficient support for agripreneurial activities is a limiting factor. Specific gaps in the lack of business courses in agriculture and ICT curricula, the lack of capacities and sustainability in innovation hubs and incubators, the limited availability of venture capital (especially mid-level financing needed for scaling) and an unfavourable business environment in general, are the main constraints for digital agripreneurs to penetrate into a sustainable digital ecosystem. The digital agriculture sector is affected by these challenges because it is a new market with unclear potential for many stakeholders, including investors.

The rise of youth digital agripreneurs is on the horizon. There is a huge opportunity in digital agriculture for young people with an entrepreneurial spirit, particularly for those entrepreneurs who are not yet active in the field of agriculture and food. It is about time young agripreneurs started to show their potential benefit to digital innovation start-ups.

5.3 Impact, risks and benefits in the process of agriculture digitalization

The economic, social and environmental impacts of digital transformation in agriculture are varied, in some cases it is possible to observe improvements in income, productivity, access to markets, risk reduction, inclusion and environmental improvements, etc. The evidence is partial, there being some isolated cases in which impacts (areas, crops, social/economic realities, etc.) and casuistry are measured where positive results have been achieved. However, it must be noted that other cases show the opposite effects. This is not contradictory, because the analysed realities tend to be different, with different or unincorporated control variables. Therefore, it can be indicated that although there are positive impacts, economic, social and environmental, these are not entirely conclusive, and a greater effort is required in developing substantive evidence in this area.

In the area of the most common and widespread technologies such as computers and cellphones, there is evidence that the use of mobile applications with price information can help to reduce price market distortions, and increase production and income, in particular for small farmers. Other areas of economic impact are: (a) supporting farmers in terms of crop growth and occurrences of pest attacks or crop failure, climate-smart adaptation; (b) precise and timely weather-based agroadvisory messages facilitating informed decisions about input use, thus leading to savings on irrigation and reducing the cost of other inputs such as pesticides and fertilizers; (c) improving food lost and waste; and (d) mobile technology and innovation bringing opportunities for youth and gender in rural areas. Also, mobile phone technologies can improve household living standards, gender equality and nutrition in rural areas, especially when women have access to mobile phones. Women seem to benefit over-proportionally from mobile phone technologies, which is plausible given that women are often particularly constrained in their access to markets and information.

Precision agriculture (PA) is one of the most well-known applications of IoT in the agricultural sector and numerous organizations are leveraging this technique around the world. There is evidence that the application of guidance systems during planting and fertilizer application leads to cost savings for seed, fertilizer and tractor fuel, and reduces working hours as operators in the field, which is translated to GHG emission mitigation. At the same time, variable rate technology (VRT) technology reports savings in terms of water use in irrigation systems, increasing productivity and saving use of pesticide. Using drones can also result in economic benefits, in particular in the area of water consumption and labour and material cost reductions. PA, and all the technologies that it includes, presents the greatest economic benefits in the application of technologies in agriculture. However, this type of technology requires higher land scales and financial resources, excluding small farmers from its benefits. On the other hand, the use of these technologies brings a great improvement in efficiency, particularly in relation to the use of people employed in agricultural operations, requiring less labour in general.

Broader technologies such as blockchain, artificial intelligence and robotics have great potential economic benefits and uses in food security. For example, there are cases where the use of blockchain for the traceability of food chains has generated significant reductions in detection of food in poor condition, allowing an early and effective reaction. These types of applications can provide consumers with more information on the origin and use of inputs in food production, generating a competitive advantage for those who use it. AI, and all its techniques, is helping to improve the use of resources used in agriculture, anticipating decisions through predictive models and maintaining 24/7 monitoring systems that ultimately increase efficiency, quality and average impact environmental of agriculture and food. Agricultural robots, sometimes known as agribots, are being applied in nursery stocking processes to grazing, as well as autonomous robotic vehicles for fertilizer application or fruit harvesting. These robots promise a reduction in production costs, improvement of the quality of products and use of inputs such as fertilizers, water and soil, but at the same time a significant reduction in human labour in these operations. However, these new technologies no longer only require financial resources and scale in the size of the farms, but they also require high integration with other technologies, processes and stakeholders. In this way, although their potential benefits are evident, with the exception of the direct impact at labour side, but indirectly in generating services around them, they generate conditions of exclusion, not only for small farmers, but also for those who do not have the conditions to be incorporated.

Finally, and increasingly relevant, digital technologies are generating large amounts of data, which are being stored and used in support of agricultural operations. However, there is a scarce regulatory framework that regulates their use, preserves privacy and promotes their proper use and interoperability. This is a task that must be addressed but requires greater emphasis to achieve the expected impacts.

5.4 Future work

The work developed has generated more questions than answers, which together with the limitations in terms of systematic and official data allow for establishing a line of work in the area of systematization of data associated with the identification of risks, opportunities and gaps in adoption and sustainability of digital technologies in agriculture at the country level, particularly in rural areas.

A second line of work corresponds to identification of the different models that allow small farmers to join the digital transformation, either from the point of view of improving the infrastructure, education and regulatory framework, as well as business models that allow promote sustainable and economically profitable solutions for the small holder. In this sense, the need to have more evidence in terms of identification of generation of economic, social and environmental impact of digital technologies in agriculture and rural areas opens up an important area of work, not only with the aim of simply amassing more evidence, but also to facilitate the leap for smallholder farmers in the ongoing process of digital transformation.

Finally, and as a third line of future work, we consider the creation of a mechanism that synthesizes the art of digital technologies in agriculture with those factors identified in this work such as cultural, educational and institutional elements, at the stage of basic elements and enablers, considering the economic, social and environmental impact. 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.


DEVELOPMENT
SKILLS

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ENDNOTES

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2. The term Industry 4.0 originated in Germany, applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products.
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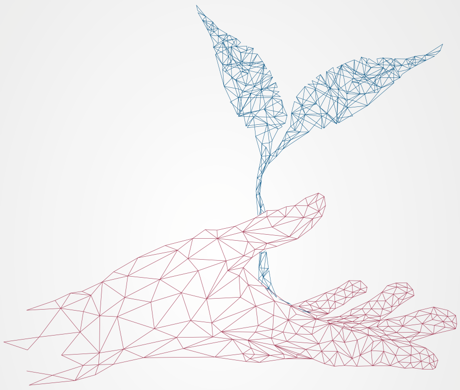

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