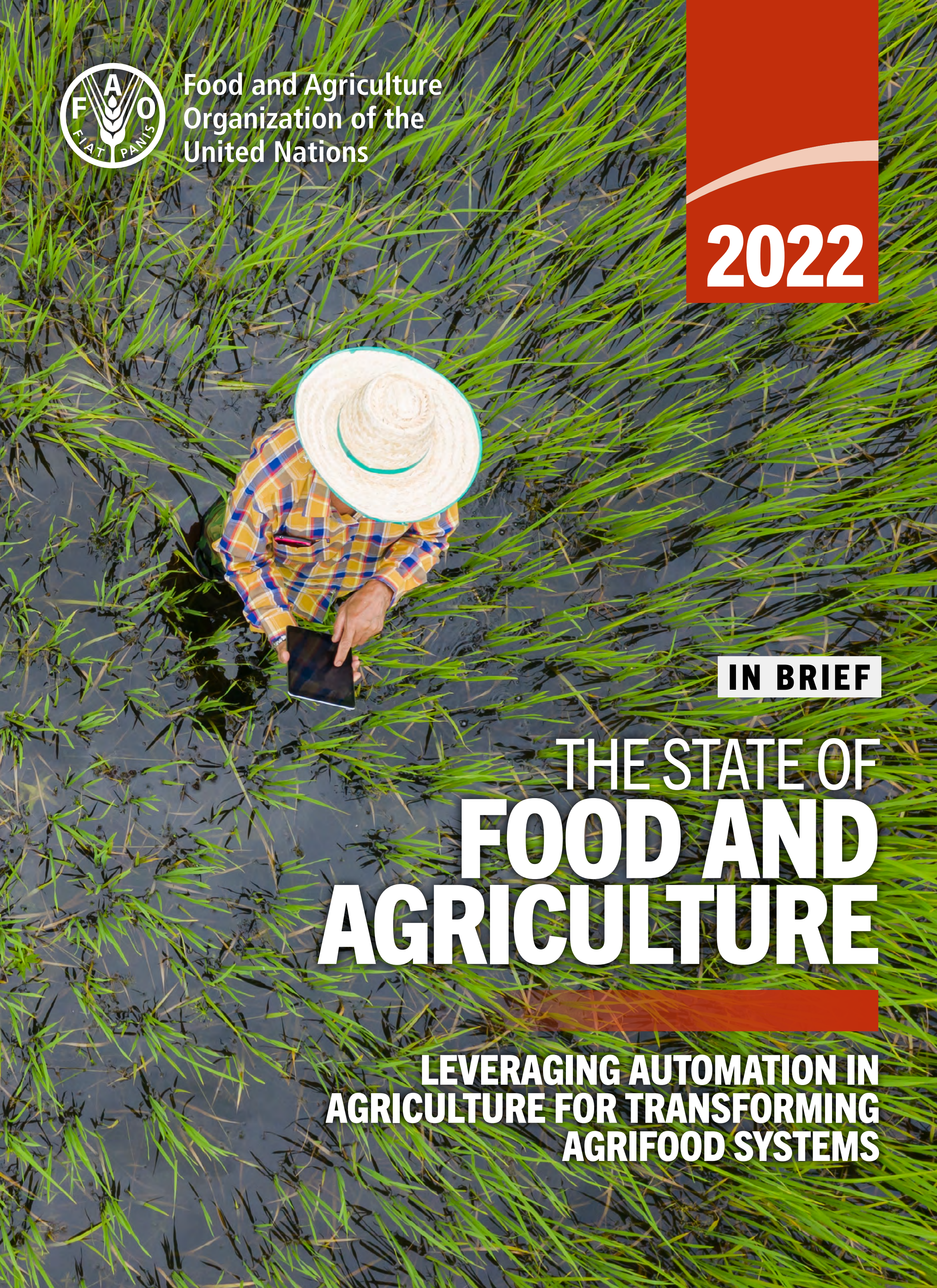


Food and Agriculture Organization of the United Nations

2022

IN BRIEF

THE STATE OF FOOD AND AGRICULTURE

LEVERAGING AUTOMATION IN AGRICULTURE FOR TRANSFORMING AGRIFOOD SYSTEMS

Required citation:
FAO. 2022. *In Brief to The State of Food and Agriculture 2022. Leveraging automation in agriculture for transforming agrifood systems*. Rome, FAO.
https://doi.org/10.4060/cc2459en

This booklet contains the key messages and content from the publication *The State of Food and Agriculture 2022*. The numbering of tables and figures corresponds to that publication.

COVER PHOTOGRAPH ©Sorapong Chaipanya/Shutterstock.com
THAILAND. Aerial view of a farmer using a tablet in a green rice field.

CONTENTS

CORE MESSAGES

1 Agricultural automation can play an important role towards achieving the Sustainable Development Goals (SDGs), not least SDG 1 (No Poverty) and SDG 2 (Zero Hunger) and those relating to environmental sustainability and climate change, by building resilience, raising productivity and resource-use efficiency, and improving food quality and safety.

2 Agricultural automation can deepen inequalities if it remains inaccessible to small-scale producers and other marginalized groups such as youth and women; certain technologies – large motorized machinery – can also have negative environmental impacts as they contribute to, for example, monoculture and soil erosion.

3 Before the digital revolution, motorized mechanization (e.g. tractors) was key to agricultural transformation worldwide; however, there have been wide disparities in adoption between and within countries, with adoption being particularly limited in most of sub-Saharan Africa.

4 If tailored to local needs and supported by digital tools, motorized mechanization still has the potential to improve agricultural productivity, leading to poverty reduction and enhanced food security, with positive spillover effects on the wider economy.

5 The use of digital automation technologies is growing, but mostly in high-income countries. Often their business case is not yet mature: some technologies are still in the prototype stages, while for others a limited enabling rural infrastructure – such as connectivity and electricity – hinders their dissemination, especially in low- and middle-income countries.

6 Investing in enabling infrastructure and improving access to rural services (e.g. finance, insurance, education) is key to ensure access to these technologies, especially for marginalized groups such as small-scale agricultural producers and women.

7 Digital automation technologies have great potential to achieve higher efficiency, productivity, sustainability and resilience. Yet, inclusive investments are needed – involving producers, manufacturers and service providers, with special attention to women and youth – in order to further develop technologies and tailor them to the needs of end users.

8 The impacts of agricultural automation on employment vary depending on the context. In situations of rising wages and labour scarcity, automation can benefit both employers and workers in agriculture and in the wider agrifood systems, creating opportunities for skilled young workers.

9 Where rural labour is abundant and wages are low, agricultural automation can lead to unemployment. This can happen if subsidies make automation artificially cheap or sudden technological breakthroughs bring automation costs down very rapidly.

10 In labour-abundant contexts, policymakers should avoid subsidizing automation, but rather focus on creating an enabling environment for its adoption – especially by small-scale agricultural producers, women and youth – while providing social protection to least skilled workers, who are more likely to lose their jobs during the transition.

11 Creating an enabling environment calls for multiple, coherent actions, including legislation and regulation, infrastructure, institutional arrangements, education and training, research and development, and support to private innovation processes.

12 Investments and other policy actions to promote responsible agricultural automation should be based on context-specific conditions, such as status of connectivity, challenges related to knowledge and skills, adequacy of infrastructure, and inequality in access.

FOREWORD

This report dives deep into a reality of agriculture: the sector is undergoing profound technological change at an accelerating pace. New technologies, unimaginable just a few years ago, are rapidly emerging. In livestock production, for example, technologies based on electronic tagging of animals – including milking robots and poultry feeding systems – are increasingly adopted in some countries. Global navigation satellite system (GNSS) guidance allows automated crop production, involving use of autosteer for tractors, fertilizer spreaders and pesticide sprayers. Even more advanced technologies are now coming onto the market in all sectors. In crop production, autonomous machines such as weeding robots are starting to be commercialized, while uncrewed aerial vehicles (commonly called drones) gather information for both crop management and input application. In aquaculture, automated feeding and monitoring technologies are increasingly adopted. In forestry, machinery for log cutting and transportation is currently a major aim of automation efforts. Many of the most recent technologies facilitate precision agriculture, a management strategy that uses information to optimize input and resource use.

Recent technological developments may astound and amaze, inspiring the desire to learn more. However, it is important to remember that technological change is not a new phenomenon and, crucially, not all agrifood systems actors have access to it. FAO has been studying this subject for decades. What we see today is no more than a consolidation point – for now – of a lengthy process of technological change in agriculture that has been accelerating over the last two centuries.

This process has increased productivity, reduced drudgery in farm work, freed up labour for other activities, and ultimately improved livelihoods and human well-being. Machinery and equipment have improved and sometimes taken over the three key steps involved in any agricultural operation: diagnosis, decision-making and performing. The historical evolution exhibits five technology categories: the introduction of manual tools; the use of animal traction; motorized mechanization since the 1910s; the adoption of digital equipment since the 1980s; and, more recently, the introduction of robotics. What is referred to as automation in this report really begins with motorized mechanization, which has greatly automated the performing component of agricultural operations. The more recent digital technologies and robotics allow for the gradual automation also of diagnosis and decision-making. As this report notes, this evolution is ongoing, but not all agricultural producers in all countries are at the same stage.

It is true that there are widespread concerns about the possible negative socioeconomic impacts of labour-saving technological change, in particular job displacement and consequent unemployment. Such fears date back to at least the early nineteenth century. However, when looking back, fears that automation which increases labour productivity will necessarily leave people without jobs on a vast scale are simply not borne out by historical realities. This is because automation in agriculture is part of the process of structural transformation of societies whereby increased agricultural labour productivity gradually releases agricultural workers, allowing them to enter into profitable activities in other sectors such as industry and services. During this transformation, the share of the population employed in agriculture naturally declines, while jobs are created in other sectors. This is generally accompanied by changes within agrifood systems, whereby upstream and downstream sectors evolve, creating new jobs and new entrepreneurial opportunities. For this reason, it is essential to recognize that agriculture is a key part of broader agrifood systems.

The report highlights the potential benefits of agricultural automation that are manifold and able to contribute to the transformation of agrifood systems, making them more efficient, productive, resilient, sustainable and inclusive. Automation can increase labour productivity and profitability in agriculture. It can improve working conditions for agricultural workers. It can generate new entrepreneurship opportunities in rural areas, which may be particularly attractive for rural youth. It can help reduce food losses and improve product quality and safety. It can also bring about benefits in terms of environmental sustainability and climate change adaptation. Recent solutions involving precision agriculture and the adoption of small-scale equipment – often more suited to local conditions than motorized mechanization using heavy machinery – can improve both environmental sustainability and resilience to climate and other shocks. Thanks to these numerous benefits, agricultural automation can also contribute to achieving several of the Sustainable Development Goals (SDGs).

However, the risks and problems associated with agricultural automation are also acknowledged in this report. As with any technological change, automation in agriculture implies disruption to agrifood systems. If automation is rapid and not aligned with local socioeconomic and labour market conditions, there can indeed be displacement of labour – the common outcome that must be avoided. In addition, automation may increase demand for highly skilled labourers, while reducing demand for non-skilled workers. If large prosperous agricultural producers have easier access to automation than smaller, poorer producers, automation risks exacerbating inequalities, and this must be avoided at all costs. If not well managed and suited to local conditions, automation, especially mechanization relying on heavy machinery, can jeopardize agricultural sustainability. These risks are real and are recognized and analysed in this report.

Yet, as the report also suggests, saying no to automation is not the way forward. FAO truly believes that without technological progress and increased productivity, there is no possibility of lifting hundreds of millions of people out of poverty, hunger, food insecurity and malnutrition. Refusing automation may mean condemning agricultural labourers to a future of perennially low productivity and poor returns for their labour. What matters is how the process of automation is carried out in practice, not whether or not it happens. We must ensure that automation takes place in a way that is inclusive and promotes sustainability.

Throughout this report, FAO shares the concept of responsible technological change to make agricultural automation a success. What does this entail?

First, agricultural automation needs to be part of a process of agricultural transformation that runs in parallel with, facilitates, and is facilitated by broader changes in society and agrifood systems. For this, it is essential that adoption of automation responds to real incentives. Thus, labour-saving technologies can further the process of agricultural transformation if they respond to growing labour scarcity and rising rural wages. On the other hand, if incentives for adoption of automation or specific automation technologies are artificially created, for example, through government subsidies – particularly in contexts where labour is abundant – automation take-up can be highly disruptive with negative labour market and socioeconomic impacts. However, it is also important that government policies do not inhibit automation, as this could lead to condemning agricultural producers and workers to a future of perennially low productivity and competitiveness. This report argues that the appropriate role of government is to create an enabling environment to facilitate adoption of suitable automation solutions, rather than directly incentivize specific solutions in contexts where they may not be appropriate, or inhibit adoption of automation in any way.

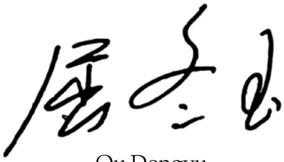
For coherence with the SDGs, automation needs to be inclusive. It must offer opportunities for all, from small-scale producers to large commercial farms, as well as marginalized groups such as women, youth and persons with disabilities. Barriers to adoption need to be overcome, not least for women. Making suitable technical solutions available for all categories of producers involves making technologies scale-neutral, that is, making them suitable for producers of all scales, or accessible to all through institutional mechanisms such as shared services. Building digital skills through education and training is also essential for facilitating adoption and avoiding digital divides based on unequal knowledge and skills.

To enhance sustainability and be truly inclusive and transformative, automation solutions need to be adapted to the local context, in terms not only of the characteristics of the producers, but also of local biophysical, topographic, climatic and socioeconomic conditions. This report is realistic and offers no one-size-fits-all solutions. The most advanced technological solution is not necessarily the most appropriate everywhere and for everybody. As the evidence presented shows, in some situations, simple technologies such as small machinery and even hand-held equipment can lead to substantial benefits for small-scale producers and enable production on hilly terrain. There are even situations where producers may be able to leapfrog directly to more advanced technological solutions. What is essential is that agricultural producers themselves choose the technologies most suited to their needs, while governments create the enabling environment that allows them to do so.

Finally, this report also argues that agricultural automation must contribute to more sustainable and resilient agriculture. In the past, the use of large-scale heavy machinery has often had a negative impact on environmental sustainability. Addressing this requires tailoring mechanization to smaller and lighter machinery. At the same time, digital agriculture and robotics that facilitate precision agriculture offer solutions that are more resource-efficient and more environmentally sustainable. Applied technical and agronomic research can help find solutions that can lead to further progress towards environmental sustainability.

This report looks in detail at these issues, presenting an objective and in-depth examination of agricultural automation, demystifying the ill-founded myths surrounding it, and suggesting ways forward to adopt agricultural automation in different country and local settings. It identifies key areas for policy interventions and investments to ensure that agricultural automation contributes to inclusive and sustainable development.

FAO firmly and strategically believes in technology, innovation and data, supported by adequate governance, human capital, and institutions, as key cross-cutting and cross-sectional accelerators in all its programmatic interventions to accelerate impact while minimizing trade-offs. No doubt, these accelerators will be catalytic for agricultural transformation in all contexts. It is my hope that this FAO report can contribute in a constructive way to the policy debate in this area of major importance for achieving the SDGs.



Qu Dongyu

FAO Director-General

SUMMARY

Throughout the ages, technological change has brought gains in productivity, incomes and well-being. Today, technological solutions are indispensable to feed a continuously growing population in the face of limited agricultural land, unsustainable natural resource use, and climate change. These solutions are needed to make agriculture more productive and sustainable across all its sectors – crop and livestock production, aquaculture, fisheries and forestry – and boost productivity within agrifood systems.

Agricultural automation has driven agricultural transformation, increasing productivity and reallocating labour. In this respect, motorized mechanization has allowed to automate the performing of agricultural operations, while, more recently, digital technologies have been creating new opportunities to automate decisions that precede the performing of physical operations.

Common fears that automation leads to growing unemployment, although understandable, are generally not supported by historical realities. Overall, automation alleviates labour shortages and can make agricultural production more resilient, improve product quality, increase resource-use efficiency, promote decent employment, and enhance environmental sustainability. Negative socioeconomic impacts of agricultural automation – such as increased unemployment – usually occur when automation is not suited to specific local needs. Risks of negative impacts can be countered by facilitating the transition of farm labourers to other job opportunities, addressing the barriers that prevent poor, small-scale producers from participating in the benefits, and avoiding policies that subsidize automation in contexts of labour abundance and low rural wages.

AGRICULTURAL AUTOMATION: OPPORTUNITIES ABOUND BUT NOT WITHOUT CHALLENGES

Any agriculture-related operation consists of three phases: diagnosis, decision-making and performing (Figure 1). Motorized mechanization automates the performing of agricultural operations such as ploughing or milking. Digital automation technologies can also automate diagnosis and decision-making. These technologies increase precision and improve productivity, with potential gains in environmental sustainability and resilience. The technological evolution in agriculture can be summarized as a move from manual tools to animal traction, to motorized mechanization, to digital equipment and finally, to robotics with artificial intelligence (AI) (Figure 2).

Against this background, the report defines agricultural automation as:

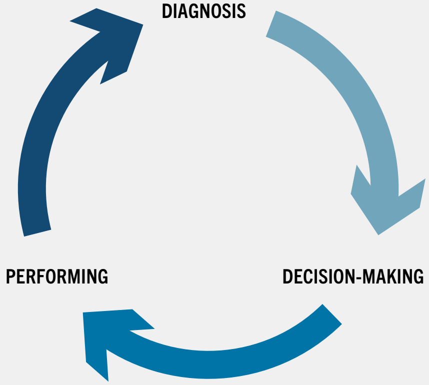
> the use of machinery and equipment in agricultural operations to improve their diagnosis, decision-making or performing, reducing the drudgery of agricultural work and/or improving the timeliness, and potentially the precision, of agricultural operations.

Agricultural automation can raise productivity and allow for more careful crop, livestock, aquaculture and forestry management. It can also provide better working conditions and improved incomes, reduce the workload of farming, and generate new rural entrepreneurial opportunities. Technologies beyond the farm can further reduce food loss and waste, enhance food safety, and enable value addition.

In many countries, declining rural labour availability – reflected in rising agricultural wages – is a main driver of agricultural automation (Figure 3). Rising consumer concerns about food quality and environmental issues are also driving investment in digital technologies. The same applies to challenges in livestock management and animal welfare that derive from growing herd sizes in livestock production.

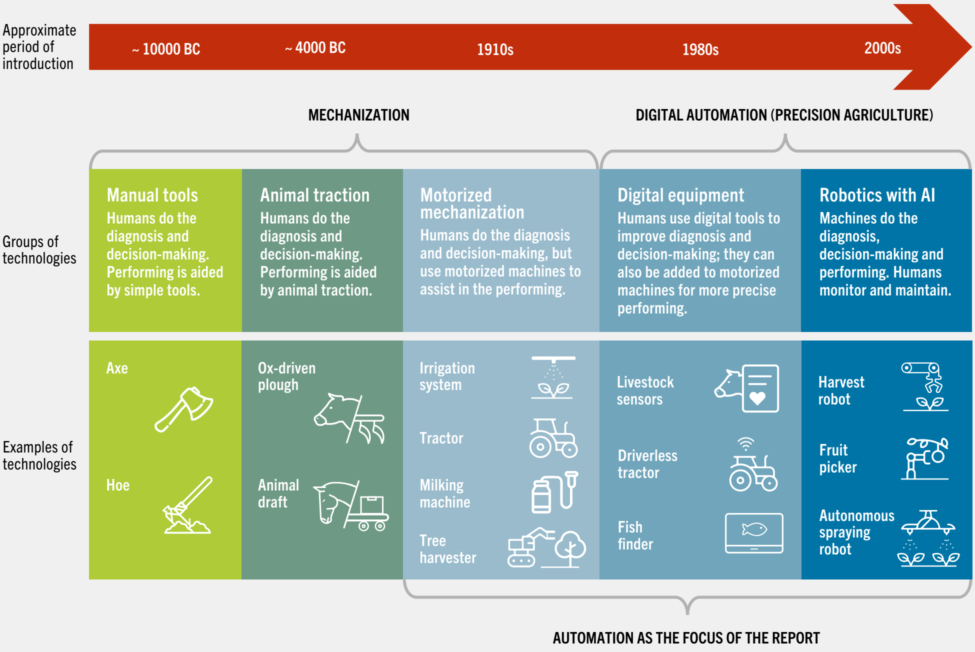
On the other hand, agricultural automation can carry the risk of exacerbating social inequalities, as larger and more educated producers have greater capacities to invest in new technologies or to retrain and learn new skills. Women and youth may face particularly significant obstacles, for example, obtaining quality education and training, as well as having access to land, credit and markets. Furthermore, automation is expected to reduce jobs that involve routine tasks, such as planting and harvesting, but increase skilled jobs. In countries with a large rural workforce, this shift in employment risks deepening inequalities. Overcoming these challenges requires reducing barriers to adoption – faced in particular by small-scale producers, women and youth – to ensure that automated solutions »

FIGURE 1 THREE-PHASE CYCLE OF AN AUTOMATION SYSTEM



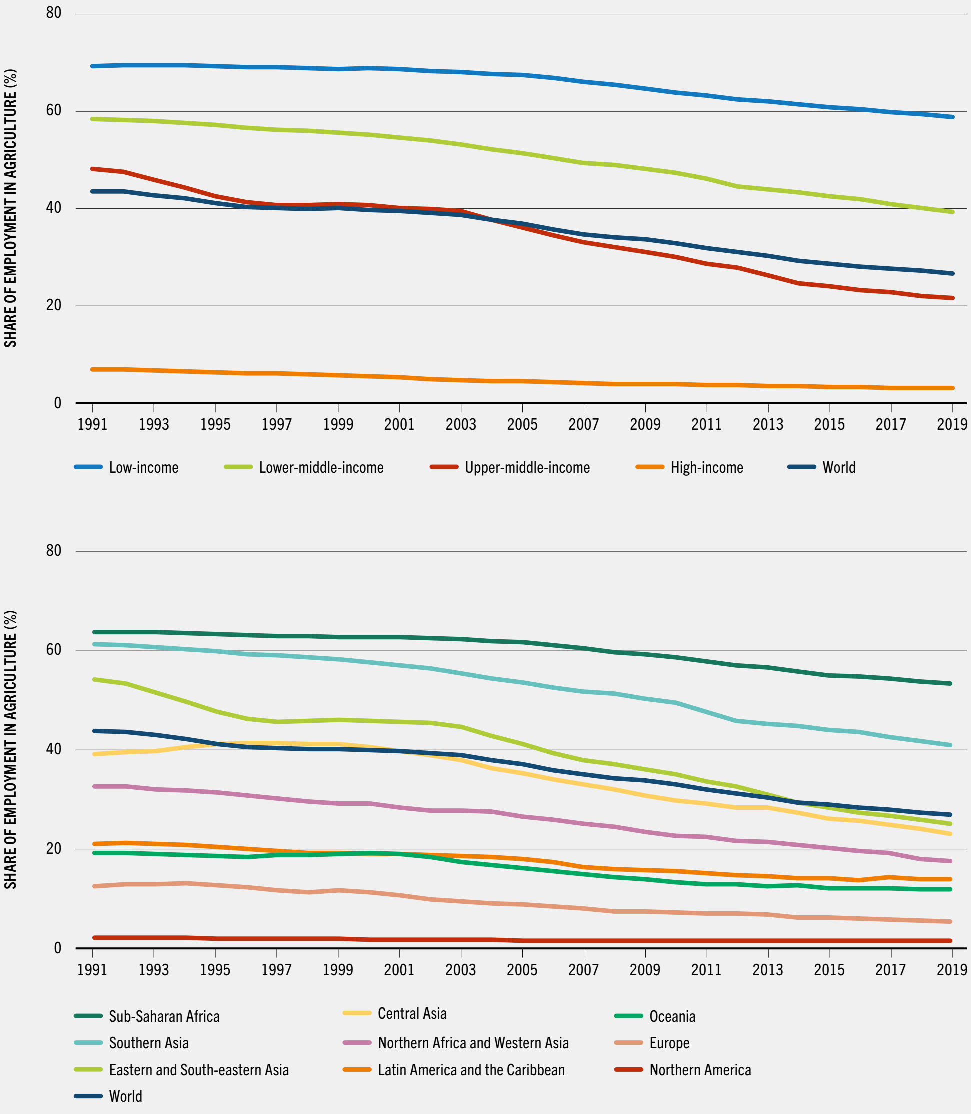
SOURCE: FAO elaboration for this report.

FIGURE 2 EVOLUTION OF AGRICULTURAL AUTOMATION



SOURCE: FAO elaboration for this report.

FIGURE 3 SHARE OF EMPLOYMENT IN AGRICULTURE OUT OF TOTAL EMPLOYMENT BY INCOME GROUP (TOP) AND REGION (BOTTOM), 1991–2019



SOURCE: FAO, 2022.

» become accessible to all scales of agricultural producers. This can be achieved through technological innovations that tailor automation to the conditions of small-scale producers, or through innovative institutional arrangements, such as shared assets or machinery hire services, that connect equipment owners to small-scale producers who pay a fee for an automation service instead of buying the machinery.

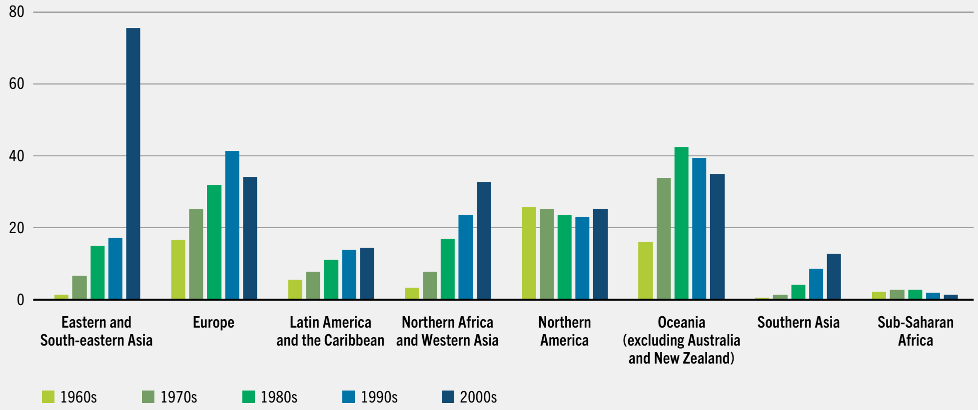
Reliance of agricultural automation on heavy machinery may also jeopardize environmental sustainability and contribute to deforestation, farmland monoculture, biodiversity loss, land degradation and soil erosion. However, some new advances in automation, especially in small equipment relying on AI, can actually reverse some of these negative impacts.

UNDERSTANDING THE PAST AND LOOKING TOWARDS THE FUTURE

Motorized mechanization has increased significantly worldwide, although reliable global data with broad country coverage exist only for tractors and only up to 2009 (Figure 4). The use of tractors was one of the most influential innovations of the twentieth century; it started in the United States of America between 1910 and 1960 and spread to Japan and Europe after 1955. Later, many Asian and Latin American countries saw considerable progress in terms of adoption of motorized machinery, in addition to the emergence of agricultural machinery manufacturing sectors in some countries. With the rise of rental machinery markets, adoption has become more widespread, allowing access for small-scale producers. However, adoption of tractors has stalled in sub-Saharan Africa in past decades, and light hand-held tools remain the main type of equipment used. Efforts during the 1960s and 1970s to promote mechanization (e.g. providing subsidized machinery and setting up state farms) proved costly and mostly failed due to governance challenges. This is changing with the re-emergence of agriculture on Africa's development agenda, which has renewed interest in automation.

Since the 1970s, digital technologies have found their way to agriculture through various applications (Table 2). Initially they were simple precision livestock technologies that managed animals based on electronic identification, which then paved the way for milking robots in the 1990s. At the same time, digital tools embodied in mechanization, such as machinery with global navigation satellite systems (GNSS), started to appear and enabled autosteer for tractors, fertilizer spreaders and pesticide sprayers. More recently, disembodied devices such as smartphones inform producers through sensors, high-resolution cameras and various apps embedded in them. These technologies can reduce costs, raise

FIGURE 4 TRACTORS IN USE PER 1 000 HECTARES OF ARABLE LAND



NOTES: Tractors refer to total wheel, crawler and track-laying type tractors used in agriculture. A fourth type of tractor (pedestrian tractor) was considered for a subset of countries as of 2000. Only countries that provided data consistently between 1961 and 2009 were considered (total of 108 countries). Central Asia was omitted due to missing data. See Annex 2 of the report for the complete set of countries, including the 33 countries for which the fourth type (pedestrian tractor) was considered as of 2000.
SOURCE: FAO, 2021.

productivity, increase flexibility in work schedules and improve life quality.

More advanced still are internet of things (IoT) solutions, used, for example, to monitor and (partly) automate decisions about the care of crops, livestock or fish. Digital services also include shared asset services, which connect equipment owners with farmers in need of their equipment.

Digital technologies hold potential also for non-mechanized precision agriculture. Methodologies for manual, site-specific fertilizer application were developed a long time ago – for example, variable rate technology fertilizer for rice – and hand-held soil scanners are available in several low-income countries in Africa and Asia. Uncrewed aerial vehicle services (i.e. drones) and GNSS are also used by non-mechanized farmers in Asia (to measure field areas) and Africa (to map field boundaries).

TABLE 2 SELECTED MILESTONES IN DIGITAL AUTOMATION IN AGRICULTURE

Year	Technology or activity	Company or organization	Country	Reference
1974	Electronic ID for livestock	Montana State University	United States of America	Hanton and Leach, 1974
1983	Executive order allowing civilian use of GPS	US Government	United States of America	Brustein, 2014 Rip and Hasik, 2002
	Drone fertilizer and pesticide application	Yamaha	Japan	Sheets, 2018
1987	Computer-controlled VRT fertilizer	Soil Teq	United States of America	Mulla and Khosla, 2016
1992	Milking robot	Lely	Netherlands	Lely, 2022 Sharipov *et al.*, 2021
1997	GNSS agricultural equipment guidance	Beeline	Australia	Rural Retailer, 2002
	N-Sensor	Yara	Norway	Reusch, 1997
2006	Automated sprayer boom section controllers	Trimble	United States of America	Trimble, 2006
2009	Planter row shut-offs	Ag Leader	United States of America	Ag Leader, 2022
2011	Weeding robot	Ecorobotix Naïo Technologies	Switzerland France	Ecorobotix, 2022 Naïo, 2022
2013	Combine harvester operator assistance system	Claas	Germany	Claas, 2022
2017	First fully autonomous field crop production	Harper Adams University	United Kingdom	Hands Free Hectare, 2018
2018	Autonomous chaser bin	Smart Ag	United States of America	Smart Ag, 2018
2022	Autonomous large-scale tractor	John Deere	United States of America	John Deere, 2022

NOTES: GPS – global positioning system; VRT – variable rate technology; GNSS – global navigation satellite system.
SOURCE: Lowenberg-DeBoer, 2022.

SERBIA
Autonomous harvester in a field.
©Scharfsinn/Shutterstock.com

THE CURRENT STATE OF DIGITAL AUTOMATION TECHNOLOGIES AND ROBOTICS IN AGRICULTURE

Digital automation and robotics applications in agriculture are extremely diverse (Figure 5). Smartphones, equipped with a range of sensors and high-resolution cameras, are the most accessible hardware for producers (especially small-scale producers) in low- and middle-income countries. However, low digital literacy in rural areas, lack of technologies suited to small-scale producers, and the relatively high cost of these technologies remain the biggest barriers to adoption.

More recently, advanced technologies such as autonomous crop robots have started to be commercialized. Drones are used to gather information and to automate input application, but their use is often strictly regulated.

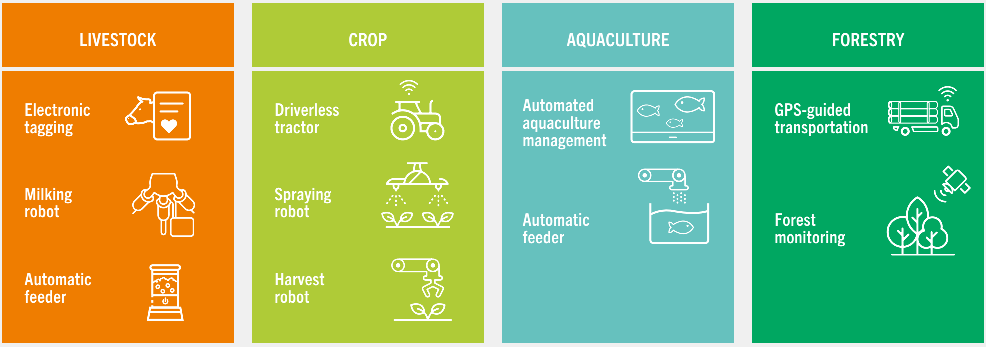
In the aquaculture sector, automation is on the rise, and in forests, much of the wood harvesting work is already highly mechanized, with mobile robots, combined with virtual reality and remote sensing, paving the way for advanced automatic machines. In addition, remote sensing is used to monitor deforestation. There is also potential for automation in controlled environment agriculture, which includes indoor agriculture and vertical farming.

Many technological solutions are already available and the direction they take and their rate of adoption are greatly influenced by policy choices. Governments need to facilitate access to these technologies – in particular for small-scale producers, women, youth and other vulnerable and marginalized groups – and ensure that they are tailored to the specific needs of producers. Ideally, governments should create a level playing field for innovative technologies to enable the private sector to meet demand for automation.

SIMPLE MOTORIZED MECHANIZATION STILL HAS A ROLE TO PLAY

While digital technologies and robotics promise great things, motorized mechanization can still bring many benefits in terms of enhanced incomes, reduced costs, less drudgery and freeing up household labour. It can also improve food safety, thanks to preservation and storage technologies, and resilience, in particular to climate shocks, by allowing farmers to complete farming activities more rapidly and be more flexible in adapting activities to changing weather. There can also be spillover effects on the wider economy. These may occur through increased demand for non-farm goods and services from agricultural households as their labour productivity improves, as well as the expansion of the non-farm economy as labour moves out of agriculture and into sectors with higher labour productivity.

FIGURE 5 SELECTED DIGITAL TECHNOLOGIES AND ROBOTICS WITH ARTIFICIAL INTELLIGENCE BY AGRICULTURAL PRODUCTION SYSTEM



SOURCE: FAO elaboration for this report.

Consequently, there is still scope for increased use of motorized mechanization in some contexts. In low- and middle-income countries, small-scale producers may benefit from small machines, such as two-wheel tractors, which are less costly and more environmentally sustainable than heavy machinery. Agricultural mechanization is therefore high on the policy agenda of many low- and middle-income countries. This is especially the case in sub-Saharan Africa, where agricultural mechanization was neglected for some time.

Manual technologies and animal traction can also still play a major role. Animal traction can be an important source of power for small, fragmented farm holdings, and advanced manual tools can reduce the need for human power. Both draught animals and advanced manual tools can help remedy labour shortages and enable higher crop yields and land expansion in many areas. In many cases, they are the most viable option to increase power supply.

THE BUSINESS CASE FOR INVESTING IN DIGITAL AUTOMATION

The business case for investing in agricultural technology rests on the potential private gains. Suppliers and producers will only make the necessary commitment if the benefits outweigh the costs. For some technologies and in certain conditions, the investment costs may exceed the private benefits; on the other hand, there may be significant benefits for the wider society. In this case, public intervention can align private benefits with the interests of society as a whole.

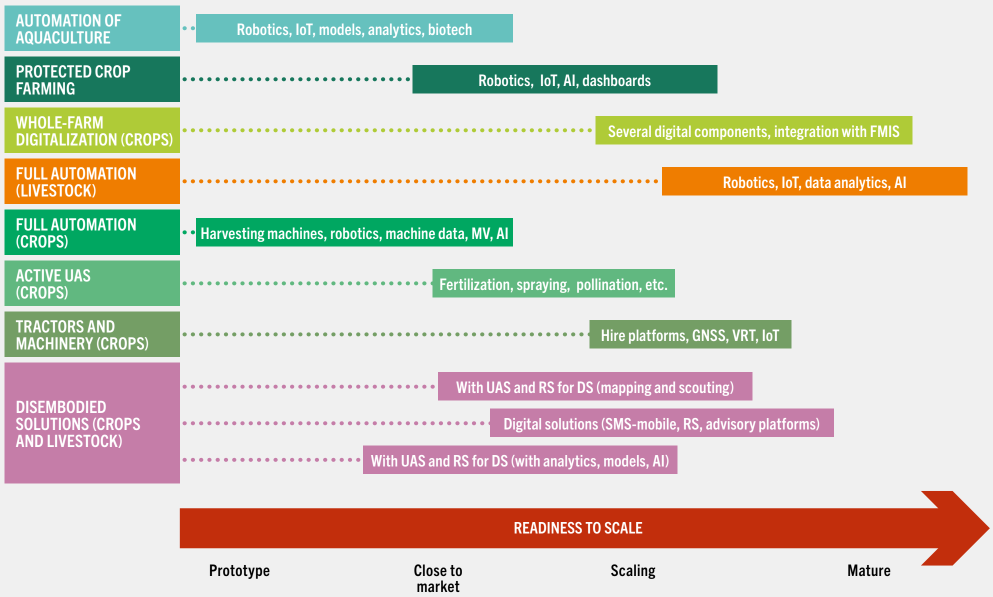
Given the scarcity of data, 27 case studies, based on interviews with digital automation service providers, were used to shed light on the business case for digital automation in agriculture. The case studies cover all world regions and agricultural production systems (crops, livestock, aquaculture and agroforestry), and represent different stages of readiness, with many still in the early stages of development and commercialization (Figure 6). The results reveal only 10 out of the 27 service providers to be financially sustainable. These ten providers – mostly based in high-income countries – use solutions that are in the mature phase (i.e. widely adopted) and mostly serve large-scale producers. More than one-third of the case studies suggest that farmers benefit from these solutions through gains in productivity, efficiency and new market opportunities. Overall, the results indicate that the business case for digital automation technologies is not yet mature, partly because many of these technologies are still in the prototype phase, but also because there are serious barriers to adoption, especially in low- and middle-income countries.

Several important lessons may be drawn from the case studies. Key factors for adoption are, first, awareness of a solution's ability to perform agricultural operations successfully and, second, the ability of farmers to handle the solution. Frequent obstacles are lack of digital literacy, and limited connectivity and electricity. These are often compounded by a reluctance to change, generally associated with ageing farming populations, which is why young farmers are seen as instrumental in a transformation towards automation. Another key factor is market conditions – strong competition among producers drives them to take more risks and adopt new technologies that promise higher productivity and efficiency. Limiting factors can be regulation of technology imports, absence of policies on data sharing, and insufficient public policies and incentives. On the other hand, if well designed, regulations or public support can be a strong driver of adoption.

AGRICULTURAL AUTOMATION PROMISES ENVIRONMENTAL BENEFITS, BUT MORE RESEARCH IS NEEDED

In high-income countries, but also in many commercial farms in low- and middle-income countries, agriculture is already highly mechanized, mainly through the use of large machinery. However, this type of mechanization has triggered soil erosion, deforestation and biodiversity loss – all contributing to reduced resilience. Innovations in

FIGURE 6 THE READINESS TO SCALE OF DIGITAL AUTOMATION TECHNOLOGIES ALONG A SPECTRUM



NOTES: UAS –uncrewed aerial system; IoT – internet of things; AI – artificial intelligence; FMIS – farm management information system; MV – machine vision; GNSS – global navigation satellite system; VRT – variable rate technology; RS – remote sensing; DS – decision support.
Readiness to scale is divided into four stages: (i) prototype – concept has been tested and demonstrated in limited trials; (ii) close to market – solution functions under real production settings, and the service provider is investigating one or more business models to reach clients; (iii) scaling – the solution has been adopted by several end users/clients, and one or more business models are profitable; (iv) mature – the solution has a dedicated client base, one or more business models are profitable, and demand is growing.
SOURCE: Ceccarelli *et al.*, 2022.

automation technologies can help address these challenges. For example, motorized mechanization can be tailored to smaller and lighter machinery (e.g. small four- and two-wheel tractors). They can minimize biodiversity loss since they do not require substantial field clearing and reshaping. Other small motorized machines, such as power weeders and mobile threshers, may also have benefits in terms of gender equality, because women can operate them easily.

Digital automation technologies that support precision agriculture also have potential to facilitate the adoption of sustainability practices such as conservation agriculture. There are success stories on the use of computers and IoT to automate greenhouses, leading to savings in water and other inputs. Small swarm robots – which are already economically feasible in certain circumstances – reduce the use of pesticides and herbicides, optimizing the use of other inputs and reducing soil compaction.

These environmental benefits are currently location-specific; what is more, many solutions are still in the early stages of development and commercialization. Therefore, research and investment in their development should expand. Transitioning to renewable energy is also important and can offer fresh opportunities to power automation, especially in remote rural areas, but – once again – research is needed to explore which off-grid renewable energy solutions can most efficiently power each type of machinery.

IMPACT OF AGRICULTURAL AUTOMATION ON LABOURERS AND CONSUMERS

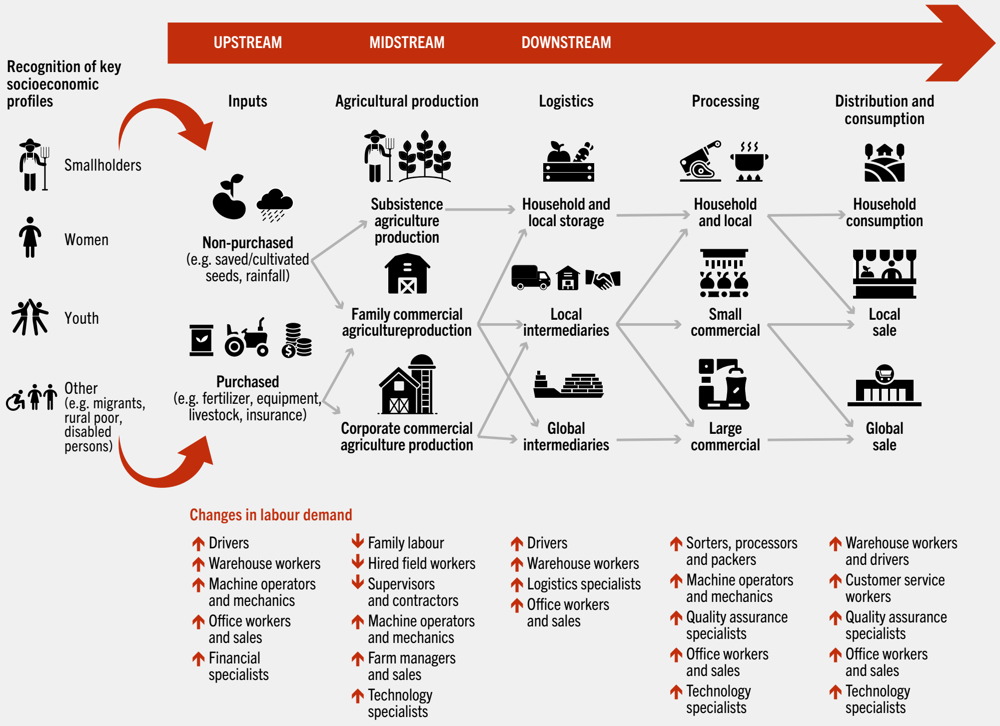
Measuring the overall employment impacts of agricultural automation is difficult because it requires large amounts of data tracking all the transformations and the associated reallocation of workers, not only in farm activities, but also upstream and downstream. As agricultural transformation unfolds, people exit agriculture to seek higher-paying jobs, and the share of people employed in agriculture declines. When all nodes in agrifood systems are changing simultaneously, it is almost impossible to ascribe labour market and socioeconomic impacts to specific occurrences of agricultural automation.

The possible effects of agricultural automation on farm employment are diverse (Figure 7). Demand for low-skill labour is likely to decrease as many tasks become automated. Meanwhile, automation boosts the demand for skilled workers. Looking at agrifood systems in their entirety, automation could decrease low-paying seasonal employment on farms but increase higher-paying and less seasonal employment upstream and downstream.

Implications of automation may also differ for different types of farms. For small-scale and subsistence farmers, automation can free up family labour, but may also allow production to expand. On family commercial farms, it can both free up family labour and reduce demand for hired labour, but if commercial agricultural activities expand as a result of automation, there may be more need for hired workers. Corporate commercial farms are the most automated with a corresponding drop in labour requirements on farms.

If automation adoption is spurred by rising wages and scarce labour, it will tend to increase labour productivity and wages without causing unemployment. If

FIGURE 7 AN AGRIFOOD SYSTEMS APPROACH TO AUTOMATION IMPACTS ON EMPLOYMENT



SOURCE: FAO elaboration based on Charlton, Hill and Taylor, 2022.

automation occurs where there is an abundance of labour, and is incentivized by subsidies that make automation artificially cheap, there is a serious risk of generating unemployment, affecting especially the least skilled, who may not easily find employment elsewhere.

Agricultural automation has significant socioeconomic impacts on consumers, because it reduces costs of food, creates new entrepreneurial opportunities beneficial to consumers – for example, by allowing the revival of nutrient-dense heirloom crops that were difficult to automate – and substantially reduces production costs for organic foods, which are currently very labour-intensive.

THE AGRICULTURAL AUTOMATION PROCESS MUST BE INCLUSIVE

Agricultural automation must involve all, in particular small-scale producers, pastoralists, fisherfolk and foresters, in addition to agricultural wage-workers, informal microenterprises and workers, landless people, and migrant labourers. Involving women, youth and persons with disabilities is particularly important.

The gender implications of on-farm automation are complex. Women lag behind men in agricultural technology adoption due to barriers in access to capital, inputs and services (e.g. extension, credit), and in some contexts, cultural norms. Policymakers need to promote gender-sensitive technology development, dissemination and service provision.

Young farmers appear to be the first to embrace the process. Agricultural automation promises new types of skilled jobs that require a human capital development and capacity-building agenda, with a focus on youth, that also facilitates a transition from low-skill manual activities to more complex technologies. However, fears that automation will lead to mass unemployment are misplaced. The automation of agricultural jobs, with the consequent evolution of the farm workforce, is a gradual process that differs across localities, crops and farm tasks. The incentives to adopt labour-saving automation are greatest for specific labour-intensive farm tasks that are easily automated at low cost. As some tasks become automated, others will remain labour-intensive.

If the available automation technologies are not scale-neutral, there is a risk that small-scale producers lack the economies of scale necessary to remain competitive. The key is for scale-neutral, low-cost automation to become ubiquitous. Limiting automation to preserve agricultural employment and incomes will only make farms less competitive and unable to expand their production. Without labour productivity-enhancing technologies, the prospects of moving poor farm workers out of poverty and food insecurity are dim.

A ROADMAP FOR EFFICIENT, SUSTAINABLE AND INCLUSIVE AGRICULTURAL AUTOMATION

Agricultural automation has strong potential for contributing to sustainable and inclusive rural development based on intensive, but sustainable, agriculture. However, achieving this potential is not automatic and depends on the socioeconomic context, as well as the policy and institutional environment in which the process of agricultural automation plays out. Countries that build the necessary physical, economic, legal and social infrastructures for digital automation stand to benefit.

Like any technological change, agricultural automation inevitably entails some disruption, bringing benefits but also giving rise to trade-offs. The report proposes a range of possible options regarding policies, institutions, legislation and investments. Together they form a roadmap to ensure that agricultural automation contributes to efficient, productive, sustainable, resilient and inclusive agrifood systems (Figure 8). Some options focus on creating a conducive business environment, in particular regarding investments in automation technologies. These need to be complemented by regulations to guarantee they lead to environmental sustainability and climate resilience. Lastly, policies and programmes must be in place to ensure the process works for all, especially marginalized groups.

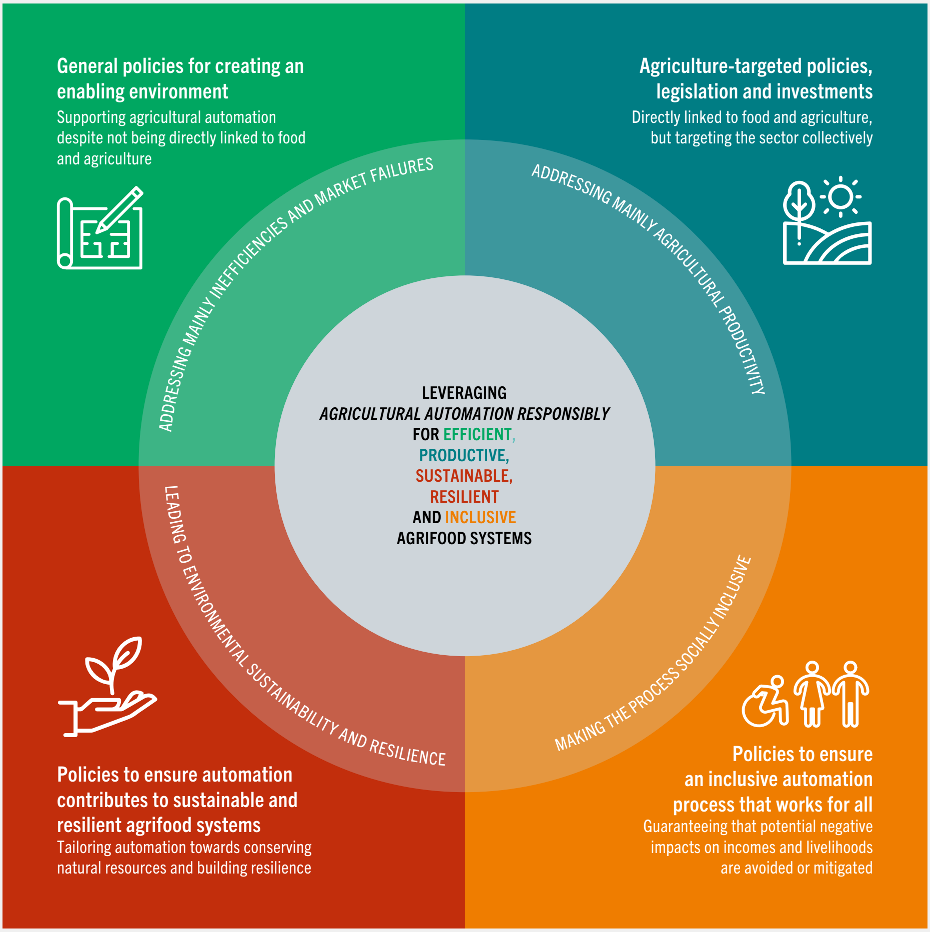
Governments will also need to balance trade-offs between economic, environmental and social objectives, and prioritize actions based on the challenges faced and their national capacities. One important cross-cutting area for government intervention is that of general services support (GSS), which represents government actions that, without distorting incentives or favouring certain actors over others (or certain sectors within agriculture), create an enabling environment for doing business in agriculture and agrifood systems.

AGRICULTURE-TARGETED POLICIES AND INTERVENTIONS ALSO AFFECT AUTOMATION UPTAKE

Agriculture-specific policies can help overcome barriers to adoption, especially for small-scale producers. Governments can influence adoption through credit policies that directly target agricultural automation. Investment loans – such as contract-based securities, loan guarantee schemes, joint liability groups, leasing, and matching grants – are the most common solution for financing automation. In addition, targeted subsidies that do not distort markets can play a role. Improved land tenure security is essential, as insecure land tenure restricts producers' access to credit because they cannot use land titles as collateral. Reducing import duties for machinery, digital equipment and spare parts, and improving customs procedures can also help to lower the transaction costs of automation technologies.

Human capital development is needed to overcome digital illiteracy, for example, through vocational training centres. Knowledge and skills of manufacturers, owners, operators, technicians and farmers must all be strengthened, with youth as a strategic target. Improving agricultural extension and rural advisory services can facilitate adoption. Public extension services have always played an important role in ensuring inclusive agricultural automation. However, the shortage of well-trained extension »

FIGURE 8 A ROADMAP OF POLICY OPTIONS TO LEVERAGE AGRICULTURAL AUTOMATION RESPONSIBLY



SOURCE: FAO elaboration for this report.

» personnel is a major constraint in most low- and middle-income countries.

Governments can fund or conduct research and development, in particular aiming at automation solutions adapted to local needs and those of small-scale producers. An important area of research is impact assessment of precision agriculture solutions in terms of profitability, environmental sustainability and inclusiveness. There needs to be a focus on both small machinery and low-tech digital solutions – more suited to local conditions and small farms – such as interactive voice response, unstructured supplementary service data and SMS.

Finally, governments need to develop quality assurance and safety standards, which may be managed by public, market and third sector organizations. Automation safety laws and regulations need to be based on consultation with all stakeholders, and must be transparent to ensure compliance.

POLICIES, INSTITUTIONS AND INVESTMENTS BEYOND AGRIFOOD SYSTEMS

General policies and investments not specifically aimed at agrifood systems can shape the enabling environment, including infrastructure. Improving poor road infrastructure can reduce the transaction costs of access to machinery, spare parts, repairs and fuel, and facilitate the emergence of service markets. Investing in energy infrastructure, for example, through development of off-grid electricity from renewable resources, is equally important. The availability of renewable energy based on local investments can buffer both shocks in the energy sector and fluctuations in fuel prices.

Improving communication infrastructure and internet connectivity across rural areas is critical for the proper functioning of agricultural automation. Legislation can play an important role – promoting public–private–community partnerships to improve connectivity and related infrastructure and provide data services and support. Investments should also target associated enabling infrastructures, such as public datasets on weather forecasts and calendars for agricultural production.

Additionally, institutions, macroeconomic conditions and broader institutional capacity are key to agricultural automation uptake. Improving credit markets is important to finance automation technologies, especially for small-scale producers. It is vital to strengthen institutional and political capacity to guide the development of automation technologies; if powerful private technology companies get there first, the consequences are potentially negative with spillover effects on wider society. What is more, if transparent national data policies are put in place – including data protection, data sharing and privacy regulations – they themselves can facilitate digital automation. Other enablers are the development of national data infrastructures and the promotion of interoperability, that is, accurate and reliable communication among machines. Finally, exchange rate policies and trade policies can affect automation patterns through the import costs for machinery, digital equipment and spare parts.

AGRICULTURAL AUTOMATION CAN CONTRIBUTE TO INCLUSIVE AND SUSTAINABLE AGRIFOOD SYSTEMS

Agricultural automation faces three specific challenges: not leaving marginalized groups behind; avoiding increased unemployment and job displacement; and preventing environmental damage. Policies can play a role in addressing these challenges and ensuring that automation contributes to an inclusive and sustainable agricultural transformation.

First, governments need to ensure that women, youth and other disadvantaged groups benefit from automation. Policies addressing disadvantages faced by women (e.g. improving women's land rights or facilitating their access to credit and extension) help increase women's access to automation. Public research and development can focus on gender-friendly mechanization technologies tailored to the needs of women. Furthermore, an agenda targeting rural youth and other disadvantaged groups is needed, ensuring that they acquire the necessary skills to perform the high-skill jobs associated with automation.

Second, governments need to safeguard against negative effects on employment. Where automation emerges as a response to market forces (e.g. rising rural wages) and replaces unpaid family labour, it is unlikely to generate unemployment. On the other hand, if artificially pushed by public efforts (e.g. through subsidized imports of machinery), it could lead to unemployment, job displacement and lower rural wages. Policymakers should therefore not promote automation before it is needed. At the same time, they should not inhibit its adoption based on the claim that it will displace labour and create unemployment. Policy support that provides public or collective goods through GSS is the most likely to allow for a smooth transition towards greater automation without creating unemployment. This includes supporting agricultural research and development and knowledge transfer services.

Third, policies need to ensure that agricultural automation contributes to sustainable and resilient agrifood systems. More advanced digital automation technologies, such as precision agriculture, can minimize or avoid the negative environmental impacts associated with motorized mechanization. Applied technical and agronomic research should explore automation solutions that best fit local agroecological conditions, and governments should facilitate adoption of environmentally friendly technologies.

In conclusion, if care is taken to address the above challenges, agricultural automation can function as a catalyst to support the attainment of the Sustainable Development Goals (SDGs), particularly SDGs 1, 2, 3, 9 and 10. The right mix of technologies – as well as appropriate policies, interventions and investments – will depend on the level of economic development, the institutions in place, local agronomic characteristics, and policymakers' objectives. It is important that policymakers recognize the context specificity of adoption and assess the particular problems facing an area (e.g. connectivity, inequality, poverty, food insecurity, malnutrition) before combining policy instruments for action. It is up to agricultural producers to choose which technologies to adopt, and up to governments to provide an inclusive enabling environment where innovation can thrive. ■

THE STATE OF THE WORLD

2022

THE STATE OF FOOD AND AGRICULTURE

LEVERAGING AUTOMATION IN AGRICULTURE FOR TRANSFORMING AGRIFOOD SYSTEMS

Automation has been shaping world agriculture since the early twentieth century. Motorized mechanization has brought significant benefits in terms of improved productivity, reduced drudgery and more efficient allocation of labour, but also some negative environmental impacts. More recently, a new generation of digital agricultural automation technologies has appeared, with the potential to further enhance productivity, as well as resilience, while also addressing the environmental sustainability challenges driven by past mechanization.

The State of Food and Agriculture 2022 looks into the drivers of agricultural automation, including the more recent digital technologies. Based on 27 case studies, the report analyses the business case for adoption of digital automation technologies in different agricultural production systems across the world. It identifies several barriers preventing inclusive adoption of these technologies, particularly by small-scale producers. Key barriers are low digital literacy and lack of an enabling infrastructure, such as connectivity and access to electricity, in addition to financial constraints. Based on the analysis, the publication suggests policies to ensure that disadvantaged groups in developing regions can benefit from agricultural automation and that automation contributes to sustainable and resilient agrifood systems.

The State of Food and Agriculture 2022 (full text)

©FAO, 2022
CC2459EN/1/11.22