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Recent Trends in Contemporary Digital Rural Advisory Services

Writer: Dr. John James, Enablers of Change Australia

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CONTEXT

Rural Advisory Services (RAS) are fundamental in supporting more than a billion small-scale farmers and other rural actors throughout the world (Nagarajan et al., 2020). These services assist them to deal with challenges and improve their livelihoods while increasing productivity and reducing hunger and poverty through innovation and strengthened capacities. Over the past ten years, digitalization in extension has received renewed worldwide interest, particularly with the advent of the COVID-19 pandemic. This has not only dramatically increased the availability and affordability of many online services, but it has escalated the urgency for the development and application of digital extension. Digitalization is considered the avenue to reach the 500 million smallholders that deserve better livelihoods and improved resilience against the adverse consequences of climate change and other environmental threats. As a contribution to the global discussion around this theme, the Global Forum for Rural Advisory Services (GFRAS) seeks to determine what kind of agricultural extension will be needed in the future to overcome today's challenges.

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BACKGROUND

While there are more than 600 million farms worldwide, more than 90% of them are family farms and 70% of them are smaller than one hectare and in most low and lower-middle income countries, the farm size is decreasing (Lowder et al., 2021; Lowder et al., 2016). Billions of people are still malnourished, millions of farmers live at subsistence level, enormous amounts of food are wasted, and our natural environment is under intense pressure. Agriculture is essential for our health and well-being, and it has been estimated that 80% of those living in developing countries depend on it for their main source of livelihood (Christiaensen et al., 2021). Some countries, such as Africa, need to double or even triple their current levels of agricultural productivity to meet demand and stave off food and nutrition insecurity (Tsan et al., 2019).

According to the World Bank, agricultural development is one of the most powerful tools to end extreme poverty, boost shared prosperity, and feed a projected 9.7 billion people by 2050. Growth in the agriculture sector is two to four times more effective in raising incomes among the poorest compared to other sectors (World Bank, 2022). The incidence of rural poverty is more than four times higher than the incidence of urban poverty and the incidence of extreme poverty is much higher among those employed in agriculture compared with those employed in other sectors (World Bank, 2020). Unfortunately, the recent impacts of COVID-19 and climate change are negatively impacting our world's food systems, resulting in even higher risks of poverty, malnutrition, and food security.

Extension facilitates the access of farmers to knowledge, information and technologies (Christoplos, 2010). GFRAS defines extension as: 'All the institutions from different sectors that facilitate farmers' access to knowledge, information, and technologies; their interaction with markets, research, and education; and the development of technical, organisational, and management skills and practices' (Davis & Sulaiman, 2016). This can be undertaken either in-person or digitally via computers, mobile phones or other electronic devices. e-Extension is defined as 'the use of electronic technologies to enhance traditional extension approaches (such as written and face-to-face) so as to enable change' (James & Raj, 2021). It is hoped that the appropriate use of these digital tools will accelerate agricultural transformation and enable smallholder farmers in developing countries to become more agile and responsive in the face of the pandemic and to become more resilient (Tsan et al., 2019).

The need to improve digital extension services is a common sentiment in developing countries (such as Africa (Rukuni et al., 2021), Ethiopia (Benson, 2022), and Indonesia (Ahmadi et al., 2021)) and also developed countries such as Australia (Cook, Jackson, & Baker, 2022; Hansen et al., 2022). It has been noted that agriculture is the least digital of all sectors in both the US and Australian economies (Blackburn & Gartner, 2017; Manyika et al., 2015). The urgency of the situation is well expressed by this quote by Akinkunmi Adesina, winner of the 2017 World Food Prize: 'Unless Africa uses modern technologies, our farmers' output will remain low and we will remain dependent on others to feed us' (Rukuni et al., 2021, p. 29).

THE FOURTH INDUSTRIAL REVOLUTION

The first industrial revolution occurred in the late 18th and early 19th centuries and marked the transition from hand-produced materials to the use of machines powered by steam and water. This resulted in greater output and an unprecedented rise in population numbers. The second industrial revolution (also known as the technological revolution) occurred around the turn of the 20th century and was a period of rapid industrial development powered by telegraph lines, railway networks, and electricity grids. This allowed faster transportation of people and information, contributing to globalization and mass production. The third industrial revolution (also known as the digital revolution) began in the late 20th century and saw the rapid development and use of computers and communication technologies, marking the beginning of the information age. The fourth industrial revolution is now underway at the start of the 21st century and is the trend towards automation, data exchange and artificial intelligence, characterised by technologies that combine hardware, software, and biology. It is marked by advances in communication and connectivity breakthroughs in fields such as robotics, artificial intelligence, nanotechnology, quantum computing, biotechnology, and the Internet of Things (IoT) (Philbeck & Davis, 2019; Schwab, 2016). In agriculture, this could see an increased use of smart sensors to collect, interpret and communicate real-time information to allow optimization of plant growth in new forms of production systems, such as hydroponic vertical farming in shipping containers (Ray, 2017; Terazono, 2020).

This fourth industrial revolution stands on the shoulders of the previous ones, in that it requires the rapid exchange of information enabled by the digital technologies of the third one, which in turn relied on the electricity and telecommunication systems of the second revolution, which would not have been possible without the machine power from the first revolution. This new revolution brings incredible opportunities for improving and optimizing agricultural systems using approaches such as artificial intelligence, IoT, and quantum computing. The development of distributed ledger technologies, such as blockchain, are enabling secure, transparent, digital identification, minimising fraud and corruption (Philbeck & Davis, 2019).

05 DIGITAL AGRICULTURE

Even though agricultural information and communication technologies (ICT) projects have existed for over 30 years (Raj et al., 2018), the term 'digital agriculture' only appeared in 2015 and refers to the use of digital information to guide decisions along the agricultural value chain (Cook, Jackson, & Cammarano, 2022; Shepherd et al., 2020). According to Fielke et al. (2020), the main benefits of digitalization centre on increased efficiency through more precise mechanization, automation, and improved decision-making. Shepherd et al. (2020) include the value created by farmers using improved animal welfare practices, and the associated traceability and transparency enabled by digital technology.

It has been estimated that the value of the digital agriculture market in 2022 is USD 18.0 billion and will rise to USD 29.8 billion by 2027, with the main driving factor being the negative impact of ecosystem change on agriculture causing farmers to search for new technology to help protect their crops and livestock from pests and diseases (yahoo!Finance, 2022). It has also been estimated that there are more than one million RAS workers in developing countries (Feder, 2005). While many farmers may prefer receiving agronomic information in-person, the often geographically dispersed audiences and limited number of service providers make face-to-face delivery challenging.

It has been reported that in India, fewer than 6% of the farmers have received information in-person. This low number is perhaps due to the spatial dispersion of farmers, especially when they relocate to houses close to their crops during the production season as they do in parts of India. Additionally, there are often challenges with limited institutional capacity of government service providers (Cole & Fernando, 2021).

Digital RAS services enable the provision of information 24/7 and can achieve a rapid and broad reach to farmers otherwise difficult to visit. It has been estimated that the traditional train and visit approach on average reaches only 10 to 20 households per day, whereas digital services can reach hundreds of thousands (Kansiime et al., 2019). Digital extension is particularly promising as it offers two-way communication at scale between farmers and advisors and additionally the large economies of scale can generate analytical insights and improve customisation of information (Fabregas et al., 2023).

The traditional ICTs of analogue telephones, radio and television are being complemented by digital services delivered via computers and mobile phones (Asenso-Okyere & Mekonnen, 2012). It should be noted that digital technology solutions are not expected to ever fully replace traditional methods of agricultural information delivery, and instead complement and enhance the impact and reach of extension projects (Baffoe-Bonnie et al., 2021; Ferdinand et al., 2021; James, 2010; Roberts & McIntosh, 2012; Tsan et al., 2019). There will always be a place for face-to-face interactions, as they are more amenable to delivering complex messages than the mass media that they complement (Norton & Alwang, 2020). Indeed, a recent study indicated that while the use of digital extension decreased the reliance of farmers on their peers for agricultural advice, it did not crowd out peer interactions centred around information exchange. Access to the service altered the nature of the peer interactions and the composition of the groups, increasing the importance of farmers who accessed the digital resources (Fernando & Yaseen, 2022).

It is asserted by Norton and Alwang (2020) that the ICT revolution has reached a tipping point where the vast majority of farmers now have mobile phone connectivity. This allows RAS practitioners to reach them with low-cost and timely messages, rather than the traditional printed material and phone calls.

There has been a dramatic decline in the number of printed mass-media products, such as fliers and pamphlets; with a similarly large increase in the use of electronic mass media which can reach large audiences in a timely manner and at low cost (Norton & Alwang, 2020). This has only been heightened by the sudden upsurge in digital communications as a response to the COVID-19 epidemic.

It is critically important that if they haven't already, that extension providers fully embrace and utilize the application of the latest ICT for their work. These new technologies can provide almost instant, personalised communication to farmers over a wide geographic area (Norton & Alwang, 2020). Digital advisory services include pest and disease management, value added services, product verification and weather information. The range and number of these services has been steadily increasing, as shown in figure 1:

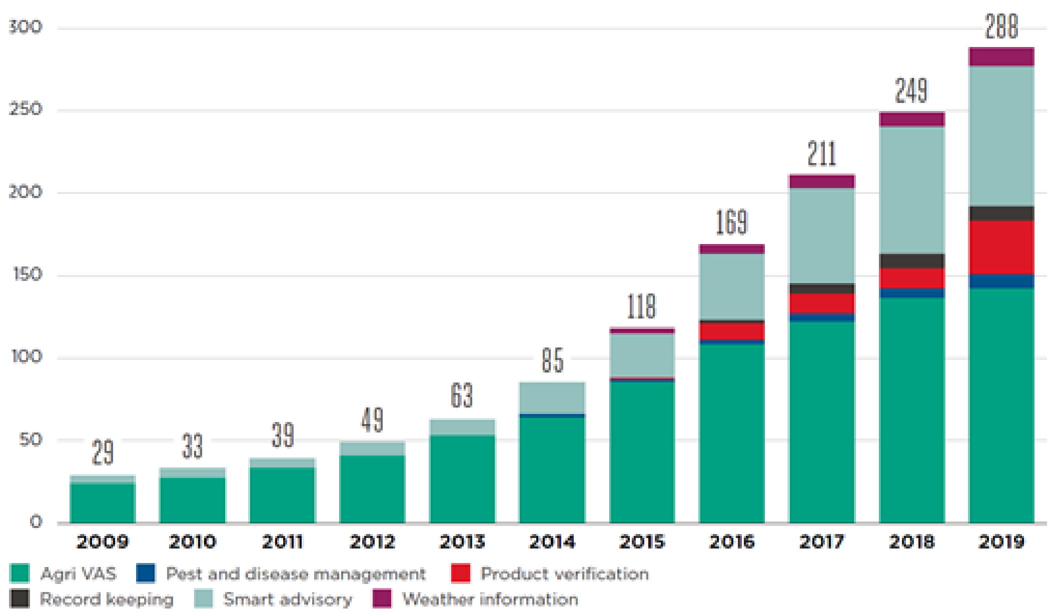

Figure 1. Number of digital advisory services available.
Source: Phatty-Jobe et al. (2020, p. 41).

Advisory services are becoming more intelligent and data-driven, delivering highly localised information that helps farmers make better decisions and in a timelier manner. These can help link climate indicators with on-farm activities, using big data analytics and artificial intelligence. Digitally powered peer-to-peer and participatory advisory services, such as Wefarm and Farm.ink, help provide crowdsourced information in places including Kenya, Tanzania and Uganda (Phatty-Jobe et al., 2020).

Digital platforms are facilitating direct interac¬tions between multiple users for the purposes of exchange, as opposed to the more traditional linear process of providing goods and services for consumers. There are now over 75 agriculture-specific marketplaces which have the potential to transform the way agricultural markets operate. It is estimated that three-quarters of these marketplaces are operated by tech start-ups and less than a quarter of them reach more than 100,000 farmers, and only one in ten reach over one million farmers (Shakhovskoy et al., 2021).

The use of digital agriculture has resulted in improvements in yield in the range of 50 to 300% (based on self-reported data) and income improvements of 20 to 100%. While these numbers most likely represent positive outliers, they demonstrate that substantial improvements are possible (Tsan et al., 2019).

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ICT TRENDS

The World Bank (2017) identified the following five trends that have been driving the use of ICT in agriculture, particularly for farmers in developing countries: 1) low-cost and pervasive connectivity, 2) adaptable and more affordable tools, 3) advances in data storage and exchange, 4) innovative business models and partnerships, and 5) the democratization of information, the open access movement and social media. It is expected that these drivers will continue to shape the effective use of ICT in developing countries in the years ahead. Each of these trends will be briefly explored, as follows.

1) The low-cost and widespread connectivity has been driven by decreasing costs, increasing competition and expansion of last-mile infrastructure. In fact, 95% of the world's population had access to a mobile broadband network in 2021, compared with just 61% in 2003. The reach and speed of broadband internet is also dramatically improving, with a 30% increase in usage in 2021, following a similar increase in the previous year. Disappointingly, the cost of fixed-broadband and mobile data remains high in the least developed countries at a price of 20% of the monthly gross national income per capita, whilst for most other countries it is at around just 2% (International Telecommunications Union, 2021). The number of mobile phone subscriptions continues to increase globally, with a dramatic climb in the number of active mobile-broadband subscriptions, while the number of fixed telephone subscriptions decline, as shown in Figure 2:

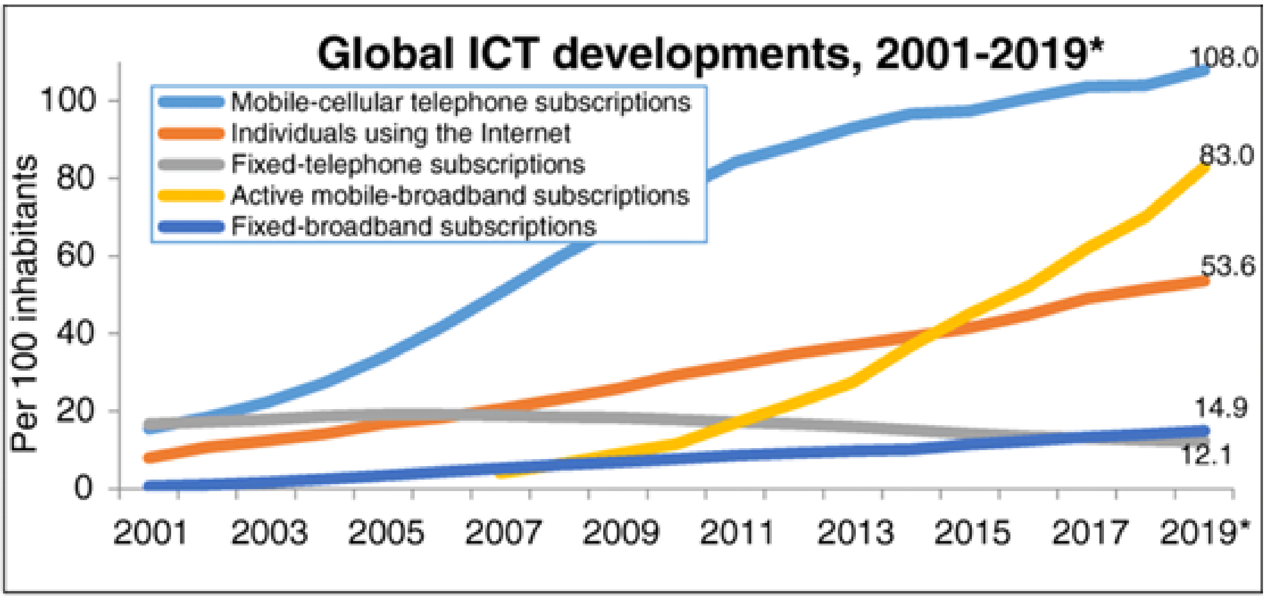


Figure 2. Global ICT developments, 2001 - 2019*
Source: ITU World Telecommunication/ ICT Indicators Database
* Estimates

1) Adaptable and more affordable tools are characterised by the purchase price for both mobile phones and computers markedly decreasing. The intuitive user interface of these new technologies and their ability to convey information visually or audibly enables use by those with limited formal education or understanding of technology. Mobile phones are increasingly being used in developing countries for information access and transactional services. Geospatial information services, such as mapping tools like Google Maps and Google Earth, allow farmers and scientists to visualise geographic data and overlay it with other useful information (such as climate and farming production information). The satellite imagery has substantially increased in quality and detail.

2) Advances in data storage and exchange are enabling users in developing countries to better access and share data, improving the use of ICT in agriculture. This is creating opportunities for more stakeholders to be involved in agricultural research and extension, as well as participating in online learning and networking. This trend is being driven by the increasing capacity of hard drives and microprocessor speeds. Cloud computing enables ready access to sharable data, tools and applications.

3) New business models and public-private partnerships are allowing entrepreneurial partnerships to develop between the public and private sectors, including new forms of ICT investment. For example, private companies which have invested in various technology and applications are now working with the public sector to provide their products and services to smallholder farmers. Business incubators are enabling innovative technologies to be quickly developed and trialled. Online marketplaces are an example of e-commerce for consumer goods in developed countries, particularly in Africa, offering great potential to serve a new generation of consumers and open opportunities for small entrepreneurs (International Trade Centre Amsterdam and University of Applied Sciences, 2020).

4) The democratization of information, the open access movement and social media are enabling the vast quantities of institutional information to be more available to the public for their use. This increases transparency and accountability, and allows open innovation where any member of the agricultural innovation system can participate in solving longterm intractable problems. Social media has moved from personal entertainment to knowledge sharing and collaboration (World Bank, 2017).

MOBILE PHONES

Mobile phones are becoming ubiquitous and allow farmers to more quickly and easily communicate and share information with other farmers and RAS providers (Aker et al., 2016). Indeed, during the pandemic, mobile phones were often the only way that many farmers could access information from extension practitioners during the frequent lockdowns (Baffoe-Bonnie et al., 2021). Mobile phones can be used to easily access social media, allowing the users to engage and share information widely (Bhattacharjee & Raj, 2016). Text messages can be sent in bulk and broadcast in near real time to hundreds of thousands of users, making information distribution exceedingly cheap (Fabregas et al., 2023). They also provide instant, convenient access to the latest agricultural, financial and market information, including farm-level information and farmer helplines (Davis et al., 2018). Simple communication apps (such as WhatsApp and WeChat) allow farmers to easily send and receive messages, voice recordings and short videos with other farmers and extension practitioners (Baffoe-Bonnie et al., 2021). It has been shown that the quantity, quality, and speed of delivering services have all increased as a result of farmers using mobile phones (Raj, 2021).

Mobile phones allow ready access 24/7 to financial information and services, such as mobile payments and micro-financing. They provide enhanced access to markets through platforms allowing bartering, trading and tendering (World Economic Forum, 2018). They also provide improved visibility of the supply-chain efficiency, such as traceability, and management of suppliers and distribution. As a result, farmers can make and receive payments, access and repay loans, and obtain customised information on seed and livestock selection. They can receive more accurate weather forecasts, reducing some of the production risks. Mobile payments can also enable governments to provide targeted subsidies to farmers. As a result, mobile apps can help reduce price variation, improve market access and facilitate financial inclusion and risk management (Alam & Shaba, 2022).

Much of the same functionality is true for tablets, though mobile phones are still far more common, and so are the focus of this report. This functionality is achieved through applications (apps) that are installed on the phones and tablets, and there has been a considerable increase in the number of apps produced for agriculture. Although it was found that most apps were related to magazines and market information, there was a prevalence of apps relating to farm management, pests and diseases, precision farming, and technical assistance. The countries with the largest number of agricultural apps were USA, Brazil, and India, representing almost two-thirds (64%) of the apps listed (Barbosa et al., 2020).

The rapid increase in mobile phone usage, particularly in developing countries, has helped overcome the problem of smaller, resource-poor farmers not being able to access relevant information in a timely manner (Aker, 2011; Khan et al., 2020; World Economic Forum, 2018).

What was once described as a pipedream (Namisiko & Aballo, 2013) has now become a reality for many small-crop farmers in developing countries. Raj (2021) found that farmers from low-income and low-education backgrounds were not discriminated against when using mobile phones to access information. A recent Australian study determined that making more informed decisions, increasing efficiency, and accessing and recording important information were the most important reasons for livestock farmers to use mobile phone apps. On the other hand, the top reasons for not using them were the amount of time required to setup and learn how to use them, despite an expectation that apps are quick and easy to use (Schulz et al., 2021). However, it should not be assumed that all farmers, particularly in developing countries, can use or even access mobile technology. It has been shown that sometimes even when these farmers have mobile phones, they use them only for voice calls (Baffoe-Bonnie et al., 2021). The use of SMS messages in agricultural extension is not new, and while the usage has increased exponentially there hasn't necessarily been a corresponding increase in yields and profits (Aker et al., 2016). However, a study focusing on marginalised farmers in remote areas of India found that the needy farmers gained more from the mobile phone technology than those who were better off. There may be some misconception that modern technologies benefit only the richer farmers, but evidence suggests that mobile phone technology can generate significant developmental effects for the poor (Fu & Akter, 2016). SMS messages were shown to increase the adoption of lime in Kenya and Rwanda, and that that repeating the same message had a statistically significant impact on the adoption, whereas providing additional information about the soil characteristics and framing the messages in different ways did not (Fabregas, Kremer, Lowes, et al., 2019).

A recent study in Pakistan by Khan et al. (2020) identified that more than three-quarters (77%) of the farmers surveyed used mobile-based agricultural advisory services, with the services provided by the telecommunication sector receiving the greatest use (37%), compared with the private sector (25%) and the public sector (18%). The greater usage was attributed to the higher network coverage and toll-free nature of the services. The public sector advisory services only provide advice about farm operations, so farmers prefer to approach the private sector ones. The study also showed that most farmers preferred voice-based content as compared to SMS, which requires a higher level of education and mobile phone skills. This was especially true for poorer farmers (Kaegi, 2015). The farmers in the study were on average aged 46 years and generally had a low level of education, with just five years of schooling. The results indicated that as the age of the farmer increased, their use of mobile phones decreased. Farmers with higher education levels were more likely to adopt and use the mobile phones for agriculture-related purposes. These findings highlight the importance of digital literacy in the application of mobile phone-enabled solutions in agricultural extension and emphasize the need for appropriate training of farmers in their use of mobile technologies.

Interactive voice response (IVR) technology allows computers to interact with people through voice and countries such as India, Madagascar and Ethiopia use it for their phone-based government extension systems. Farmers can listen to pre-recorded information and can also record new questions. While more expensive than text-based systems, it is inclusive of users with low levels of literacy (Fabregas et al., 2023).

It was shown that an IVR mobile advisory system providing advice to cotton and cumin farmers in India increased self-reported adoption of recommended seeds (Cole & Fernando, 2021). An example of an IVR/SMS system is the 8028 Farmer Hotline in Ethiopia which was launched in 2014. This is helping remote rural smallholders to receive up-to-date information in a timely manner, simply by calling the toll-free short code 8028. (Anon, 2018). This service has reached more than 5.5 million registered users and in the last six months of 2021, it reached almost 20,000 farmers with various season agronomic messages, delivered in five different languages (Team Digital Green, 2022).

Mobile phone-based money transfer (MMT) allows customers to use their phone like a bank account and a debit card, enabling activities such as long-distance remittance, micro-payments, and informal airtime battering schemes. It is becoming increasingly popular in developing countries and particularly suits those with small, irregular or cyclical incomes. A study involving 379 farmer households in Kenya found that while almost all of them (96%) were aware of MMT, only just over half (52%) had used them. The services were more likely to be used by well-educated males. It was found that the largest proportion (32%) of money received via MMT was used for agriculture-related purposes, such as the purchase of seed, fertilizer for planting and topdressing, farm equipment/implements, leasing of land for farming, and paying farm workers). Importantly, the study found that use of MMT services significantly increased the household annual input use by $42, household agricultural commercialization by 37% and household farm incomes by $224 (Kirui et al., 2013).

It has been estimated by the World Economic Forum that if approximately 275 to 350 million farms gain access to mobile-based services by 2030, then 250 to 500 million more tonnes of food could be produced, and 20 to 65 million fewer tonnes of food lost. The total additional income would be US$100 to 200 billion, representing an increase of 3 to 6% of the total production value. The environmental impacts would also be considerable, with 50 to 100 fewer megatonnes of CO2-equivalent being produced and 40 to 100 billion cubic metres of water saved (World Economic Forum, 2018).

To achieve these results requires mobile transmission infrastructure, broadband connectivity, and access to low-cost mobile phones with affordable data plans. Farmer agricultural education and training is necessary to ensure that they can make use of the insights and information available. They will also need training and ongoing support to maximize their ability to use the mobile services. Ideally these services would need to be affordable or free, to help speed up their adoption and use. Care needs to be taken to ensure that the services are scaled comprehensively, so that illiterate farmers are not excluded.

An example of the use of mobile phones in agriculture was RML AgTech Pvt. Ltd, previously known as Reuters Market Light (RML). They used a mobile app to provide farmers with personalized agricultural information from pre-sowing to postharvest. Their decision-support technology provided information on more than 450 crop varieties and more than 1,300 markets. Farmers received support in their local language from call centers and via SMS, voice and mobile applications. Farmers who used this mobile service reported income improvements between 8 and 25% (World Bank, 2017; World Economic Forum, 2018).

Another example is Avaaj Otalo (AO), a mobile phone-based technology service in India that both pushes information to farmers via voice calls. It also allows users to call a hotline, ask questions, and receive a recorded response from agricultural scientists and local extension workers. Callers can also listen to answers to questions posed by other farmers (Fernando, 2021). It provides weekly push content, delivering time-sensitive information such as weather forecasts and pest control strategies directly to farmers. The delivery of information through voice messages, as opposed to text-based approaches, reduces the need for high literacy skills (World Economic Forum, 2018).

A randomised experiment showed that AO had a range of important, positive effects on farmer behavior. It significantly changed farmers' sources of information for sowing and input-related decisions and in particular, farmers relied less on commission-motivated agricultural input dealers for their pesticide advice. Farmers were more likely to switch to a pesticide that was both more effective against pests, and dramatically less toxic to humans. Farmers benefiting from advice also changed investment decisions, demonstrating more knowledge about cumin (a high-value cash crop) and planting more of it. Interestingly, it was found that farmers appear willing to follow advice without understanding why the advice was correct. The average respondent did not demonstrate improved agricultural knowledge, though there was some evidence that educated farmers learnt from the service. Overall it was shown that this relatively low-cost extension service (costing as little as US$0.60 per farmer per month), was effective at changing behaviour (Cole & Fernando, 2012). A more recent two-year research project involving 400 farming households across 40 villages in India found that 90% of the households used the service and while it facilitated changes in technology adoption, there was no evidence of increase crop yields or profit. There was however a significant increase in the level of trust in mobile phone-based programs as a source of agricultural advice, with an increase of more than 6 units on a 10-point scale occurring by the conclusion of the research (Cole & Fernando, 2021). Another study showed that using mobile phones to access the AO service reduced reliance on peer agricultural advice, and did not crowd-out peer interactions. Instead, those farmers were more likely to recommend inputs to their peers, who, in turn, prioritized interacting with them (Fernando, 2021). The final example is that of Direct2Farm, which provides short credible SMS and voice content for a range of crops and livestock to smallholder farmers in India via their mobile phones. A study of the 400,000 registered users showed that 40% of them became regular users and that 76% of the respondents reported taking action based on the information received.

Older farmers were less likely to take action based on messages received on the mobile phone, largely due to their not being able to understand the messages because of language or hearing issues. Women also reported problems understanding the language used in the messages. Overall, the service was effective at reaching a large number of farmers in different localities. It was noted that farmers expressed a preference for text messages over voice messages, as they could more easily save the messages for later, and show them to a technical advisor if they required further information. Overall, the smallholder farmers felt that their knowledge had increased and marginal farmers reported gaining yield benefits (Kansiime et al., 2019).

SOCIAL MEDIA

Social media are a form of electronic communication that allows users to interact, create, share, retrieve, and exchange information and ideas in various formats (including text, audio, pictures, and video) (Bhattacharjee & Raj, 2016). Social media has revolutionized communication worldwide and while the more popular ones are Facebook, Twitter, YouTube, WhatsApp, and Instagram, there are a multitude of social media platforms. Many began as web-based platforms, but most are now also distributed as smartphone apps. Due to the diversity of social media platforms, the existing body of published information, and the wide use of them by RAS practitioners (Aguilar-Gallegos et al., 2021; Bhattacharjee & Raj, 2016; Klerkx, 2021), this literature review will focus on other less used contemporary digital tools.

VIDEOS

Videos can help scale the effectiveness of extension activities and reduce the necessity for one-on-one visits with farmers, particularly in remote areas (Davis et al., 2018). A study using video-based group extension with low-caste female farmers in India found that it increased crop yields by 20 to 30% (Baul et al., 2020). Among maize farmers in Uganda, extension videos influenced cropping patterns (Van Campenhout, 2017). A recent meta-analysis combining the effects of several studies suggested that yields increased by 4% as a result of video-based interventions (Fabregas, Kremer, & Schilbach, 2019).

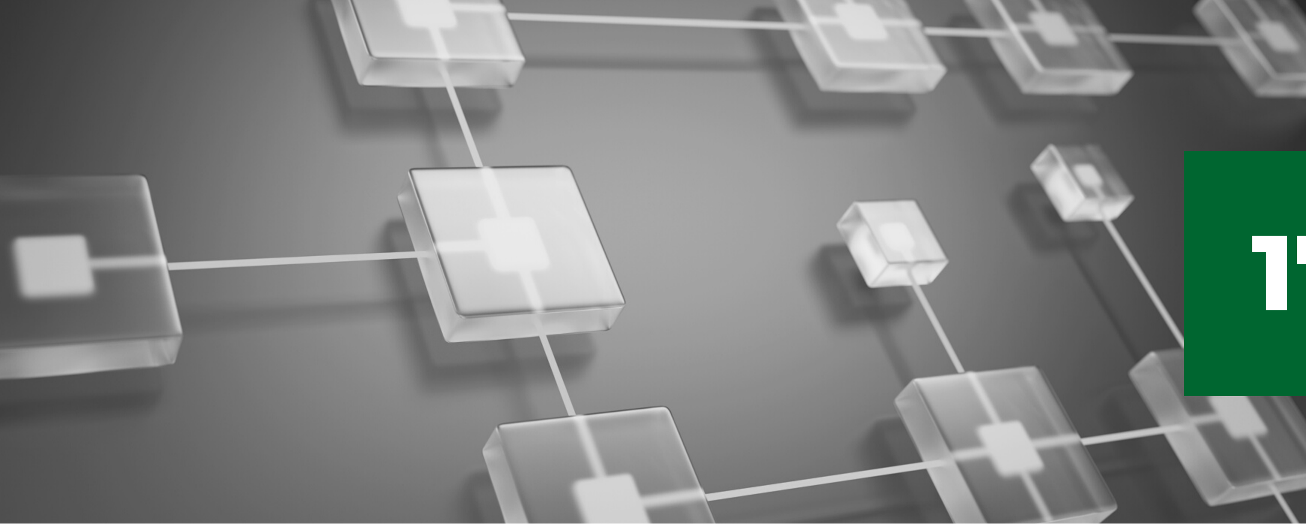
An example is the Digital Green (DG) research project that uses digital video to disseminate targeted agricultural information to small and marginal farmers in India. The project uses a participatory process for content production, often involving local farmers discussing the benefits of a particular technique and includes clear instructions that others can follow. The DG process includes the local extension agent and a content producer who records the videos using relatively inexpensive equipment (a camcorder or smart phone, a microphone and a tripod).

Video editors then create the short videos, checking for the accuracy, clarity, and completeness of the content. The final product is uploaded to the website but DVDs are also mailed to selected villages where a TV and DVD player has been provided. Various formal and informal group activities ensure the message is communicated to the local community in multiple ways to reinforce the message.

As opposed to some systems that only use information-intensive approaches and communication technology to deliver information to farmers, Digital Green amplifies the effectiveness of the existing, people-based extension systems by working with them. While video provides a point of focus, it is the people involved and the social dynamics that enable this approach to work. A detailed evaluation found that 85% of farmers in the target communities adopted at least one new agricultural practice compared with only 11% of the farmers in the control villages where the traditional train and visit (T&V) approach was used. It was estimated that extension agents spent 80% of their time in T&V control villages convincing farmers to adopt new techniques, whereas they only spent 20% of their time doing so in DG villages. A cost-benefit comparison indicated that the project approach was at least ten times more effective per dollar invested than the traditional T&V approach (Gandhi et al., 2009).

SMART FARMING AND IOT

Smart farming solutions are powered by the Internet of Things (IoT), which connects sensors and actuators via networks to computing systems. These allow farmers to optimise the production processes and growth conditions, while minimising input resources and costs. For example, these solutions can assist farmers monitor water levels remotely, identify optimum harvest dates and detect crop diseases. The data gathered provides an opportunity to better match supply and demand, while also ensuring ethical and sustainable sourcing of products. Unfortunately, the sensors can be very expensive to purchase and challenging to use appropriately (Phatty-Jobe et al., 2020). It has been estimated by the World Economic Forum (2018) that if IoT was implemented in 50 to 75% of the supply chains in developed countries by 2030, then 10 to 50 million fewer tonnes of food would be lost in distribution.



BLOCKCHAIN

Blockchain is a type of distributed ledger technology and can be used to monitor information about food moving through the supply chain as well as reducing transaction costs and the time required for processing payments. This technology makes it impossible for the collected information to be censored or modified by anyone along the supply-chain. This can then allow a premium to be charged for certain products as consumers are more confident about the source and quality of their food. One study determined that tracking food production information using conventional methods took almost seven days, whereas blockchain reduced that to just two seconds (Kamath, 2018). This could help reduce the response times when contaminated foods are discovered and would allow selective recalls. It has been estimated that if blockchain technology was used to monitor the information in 50% of the world's supply chains, the efficiency gains could lead to a reduction in food loss by 10 to 30 million tonnes (World Economic Forum, 2018).

PRECISION AGRICULTURE

Precision agriculture allows farmers to make decisions to optimise their economic returns, based on countless variables. Precision agriculture uses ICT, automation, robotics and decision-support technologies to take the guesswork out of many farming operations, making it more efficient, profitable and sustainable.

It has been estimated that precision agriculture could benefit 80 to 150 million farmers by 2030, though mostly for large and midsize farms. The associated production and environmental benefits would be 100 to 300 million tonnes more crops produced and 5 to 20 fewer megatonnes of CO_2-equivalent emitted. As a result, the cost of farming could drop by $40 to 100 billion and water use could decrease by 50 to 180 billion cubic metres (World Economic Forum, 2018).

CHALLENGES OF SCALING TECHNOLOGY SOLUTIONS

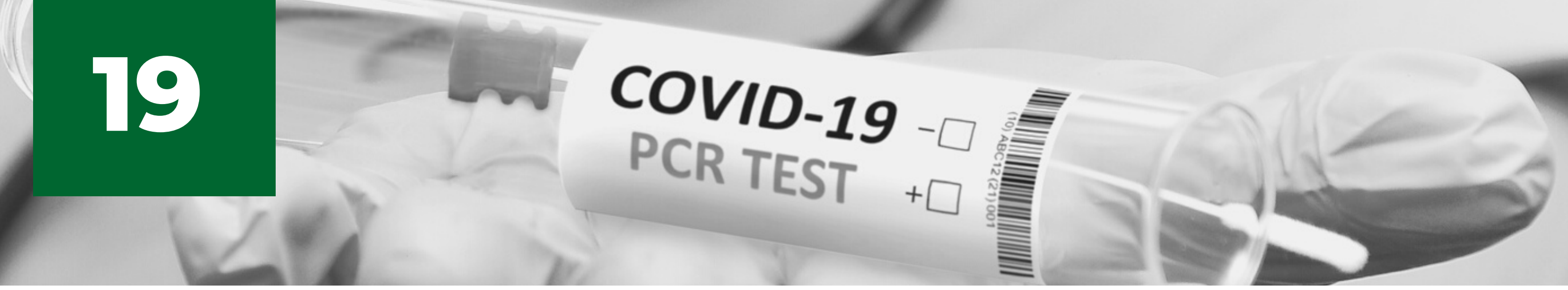
TIt is acknowledged that it is extremely difficult to scale innovations in food and agriculture systems. This is due to the fragmented nature of the marketplace, the ability and willingness of customers to pay, the operational complexities, and finally, interventions made by governments to address the food security imperative (World Economic Forum, 2018).

The development and commercialization of technologies can be a long, complicated, and risky process. The innovations need to be translated into market offerings that meet the needs of the various customers, creates consumer demand, navigates intellectual property regulations, and finds supply-chain partners. It is then difficult to make these technology innovations universal as there are very few companies that can singlehandedly achieve the desired outcome of inclusive, sustainable, efficient, and nutritious and healthy food systems. It is more likely that a number of organizations from the public and social sectors are needed to achieve success (World Economic Forum, 2018). Therefore, many food systems technology innovations either fail or don't reach any meaningful scale. It was estimated that only 1.1% of technology innovations across all sectors expand, and food systems-focused technology innovations experience a similar trend (Ewing Marion Kauffman Foundation et al., 2017).

As detailed by World Economic Forum (2018), the key enablers to creating an environment that enables innovators to create solutions for local challenges and successfully upscale them include:

- **Access to flexible forms of capital from start-up to scale**
- **Technology and economic infrastructure**
- **Managerial and technical talent**
- **Assistance on technology and business model development**
- **Business support services**
- **Enabling policies and regulations**
- **A diverse mix of institutions: academic, business incubators, governments, philanthropic actors, private enterprises.**

Scaling technologies requires more than just providing support to individual innovators, as support structures need to be put in place to enable smallholder farmers to adopt the new technologies. This could include investments in basic agricultural and technology infrastructure (roads and bridges, storage and broadband or connectivity). Appropriate tax and regulatory policies are important, as are suitable policies to drive innovation (World Economic Forum, 2018).



IMPACT OF COVID-19

The sudden and unexpected arrival of the COVID-19 pandemic left many extension practitioners wondering how to adjust their practices to avoid travel and accommodate physical distancing requirements. However, this was not the first time that RAS personnel have responded to a disaster, having successfully dealt with human health issues (such as HIV/AIDS, Ebola, and avian flu) and natural disasters (including floods, fires and droughts). Lessons from past experiences include that capacity strengthening and access to the right tools and channels enable targeted messages to those in need, and that local farmers and others along the value chain need to be supported throughout the process (Chen et al., 2020).

In this case though, the disruption created a tipping point (Meera, 2020) for the adoption of online technologies and as a result, digital extension services have dramatically increased in most developing countries, especially where there is good infrastructure (Siankwilimba et al., 2022). For example, Zoom (the web conferencing software) jumped from 10 million daily meeting participants in December 2019 to 300 million in April 2020, which has now levelled out at 350 million (Wise, 2022). The 30-fold increase in just six months demonstrated how quickly many people changed their routines and work patterns. Other applications, like WhatsApp, have also experienced increased use, with a 40 to 50% increase during the beginning of the pandemic (Perez, 2020).

Restrictions placed on the movement of people and goods as a result of the pandemic have reduced economic activity in most sectors and most countries, affecting production, distribution and consumption. The global economy was predicted to shrink by 4% in 2021, instead of the predicted growth of 4% over the year. This negatively affected the global trade in goods and unfortunately developing countries and their citizens are particularly vulnerable to recessions in global economic activity (United Nations, 2021). It is estimated that the equivalent of 400 million fulltime jobs were lost worldwide and that the lower income groups have been disproportionately affected (International Labour Organization, 2020).

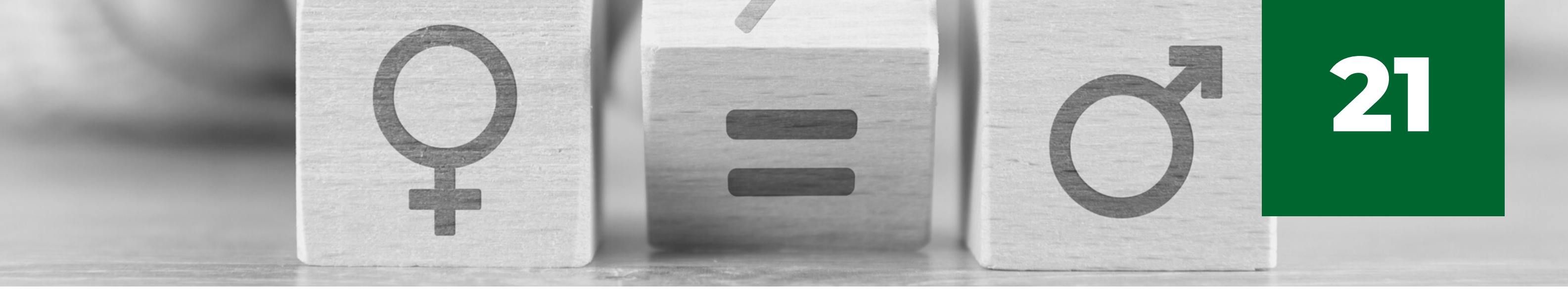
The mitigating strategies put in place to minimise the spread of COVID-19 have created unintended consequences on the already vulnerable smallholder farmers by limiting access to information and technologies. The pandemic not only resulted in the death of many famers and RAS practitioners, it also impacted the mental health and well-being of the survivors. However, a review of over 60 papers determined that while nearly all extension models were disrupted, most RAS practitioners incorporated some form of digital communication to keep communicating with their farming communities (Siankwilimba et al., 2022). Unfortunately, the pandemic has magnified the systemic challenges faced by smallholder farmers in developing countries (Phatty-Jobe et al., 2020).

HUMAN CENTRED DESIGN

Human Centred Design (HCD) ensures that products being developed address the specific pain points of the different intended users. Design thinking is a human-centred approach to innovation that integrates the needs of people, the possibilities of technology, and the requirements for business success. It is an iterative process that involves five steps: empathise, define, ideate, prototype and test. This puts users and their experience at the centre of the design process, meaning the resultant product or service is much more likely to meet the needs of the users. This is critical in the design and development of digital agriculture services, as their users have a diverse range of experiences and skills. The style of content delivery is as important as the quality of the information being presented (Phatty-Jobe et al., 2020).

Co-design, together with co-creation, co-development and co-evaluation, has been shown to improve the outcomes for farmers in India (Vedeld et al., 2019) and is recognised as good practice in the Philippines (Gabrillo & Torres, 2022). Often the development and design of technological solutions is driven by the development organisation's R&D team, with little regard for the actual farmers' requirements (Eastwood et al., 2022). Co-creation should be seen as an opportunity to build capacity and empower stakeholders (Ferdinand et al., 2021). Responsible Innovation (RI) has overlapping features with HCD and has been defined as 'a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products' (Von Schomberg, 2011, p. 9). There are four dimensions to responsible innovation (Stilgoe et al., 2020): anticipation (defining the possible scenarios for an innovation and its possible consequences), inclusion (involving diverse stakeholders), reflexivity (reflecting and questioning) and responsiveness (changing the design in response to feedback).

RI and HCD share features such as empathy for end-users, stakeholder participation, and reflexivity on design outputs (Steen, 2012). McCampbell et al. (2021) propose that responsible design of digital agricultural solutions requires asking critical questions and deliberating about the potential consequences of the proposed technological solution. This is particularly important in low-income countries where power imbalances are prevalent and difficult to address. Responsibilisation is the process of setting behavioural standards for all those involved in implementing an innovation, and focuses on the moral responsibilities (Rijswijk et al., 2021). A recent example of co-design is the Ushauri digital information service implemented in Tanzania where an automated hotline for farmers was created. The system provided access to pre-recorded messages and allowed farmers to leave questions as voicemail. Extension agents could then listen and respond to the questions, sending replies via an automated push-call. As a result, farmers were actively engaged with the service and the extension agents were able to answer questions with reduced effort compared to traditional means (Ortiz-Crespo et al., 2021).



GENDER REPRESENTATION

An analysis of the digital agriculture in 47 sub-Saharan African countries determined that a gender divide in use of technology is evident, with girls and women lagging in digital literacy (FAO & ITU, 2022). Little progress has been made in regard to gender equity for women, particularly in Africa where modest progress has been noted (Tsan et al., 2019). Women, particularly in India and Africa, often feel marginalised or ignored as a result of unequal power dynamics and their lack of inclusion in RAS materials such as videos and fact sheets. Yet women in India account for 80% of farmers working with livestock and 33% working in the cropping sector, and overall they represent half the agricultural workforce. These percentages are only likely to increase with more men leaving the agricultural workforce to find employment elsewhere. Many videos and printed material only portray images of men as farmers. Instead, they need to be better representing the women who are more likely to be accessing the information, so that they perceive the information as being relevant to them (TNN, 2022). ICT-based extension information may reduce gender bias by improving the access to information by women in developing countries, particularly if they have ready access to ICT (World Bank, 2017).

The pandemic has amplified the barriers many women face that make it harder for them than men to benefit from the opportunities of the digital economy and e-commerce. Not only are women more exposed to the virus because they are more likely to work in service sectors or as front-line workers, but they are often excluded from policy formulation processes that affect pandemic responses. Women commonly take up more unpaid work than men (including domestic chores and child home schooling during lockdowns) while having fewer resources to draw on, experiencing inequalities in access to the Internet and other resources that enable them to launch businesses. UNCTAD and its partners in eTrade for Women have worked to address some of these challenges, through programmes concerned with online training and support, improved data gathering and providing access to resources that enable women to participate actively in the digital economy (United Nations, 2021).

Chander and Rathod (2020) suggest it would be more effective if female extension workers disseminated the technologies to the female farmers, using both formal and informal modes. Furthermore, using a group mobilization approach, a small number of leading female farmers could be trained and used as a connection between farmers and other RAS professionals. Using a gender lens will assist extension practitioners and policy makers to better understand and respond to the needs of females in the innovation system (Jarial & Sachan, 2021) and a humanized extension approach may more successfully support all farmers (Cook et al., 2021).

DIGITAL DIVIDE

Latest figures show that over five billion people are using the Internet in 2022, or roughly 63 per cent of the world's population. This is an increase of almost 17 per cent since 2019, with almost 800 million people estimated to have come online during that period. However it should be noted that three billion people still remain unconnected to the internet, with the majority located in Southern and Eastern Asia, and in Africa (Anon, 2022). The statistics reveal a connectivity digital divide separating the digitally connected from the digitally excluded, with 96 per cent of them living in the developing world. The figures reveal that the share of Internet users in urban areas is twice as high as in rural areas. There is also a generational gap in that 71 per cent of the world's population aged 15 to 24 are using the Internet, and a gender gap in that 62 per cent of internet users are men. Unfortunately, while that digital gender divide has been reducing across all regions, women remain digitally marginalized in many of the world's poorest countries, where online access could potentially have its most powerful effect (International Telecommunications Union, 2021).

BARRIERS AND CHALLENGES

Lack of digital infrastructure and poor digital literacy are cited as the greatest barriers to adoption of digital technology by farmers (FAO & ITU, 2022; Shakhovskoy et al., 2021; Tsan et al., 2019). Other studies have identified concerns about data privacy and security, software and system compatibility, and understanding how to use and gain value from the data (Drewry et al., 2022; Fabregas, Kremer, & Schilbach, 2019). The types of failures in digital agriculture have been divided into three categories by Cook, Jackson and Baker (2022). User failure, referring to farmers and other users who are not interested in change, but this is seen as the least likely cause of failure. The second is technology failure where the technology is too complicated or expensive, and most commonly occurs when a technology has been transposed from another industry to agriculture. The third and most common cause is process failure, where the people and organisations using the technology have not been sufficiently engaged and their needs considered. Future challenges include increasing the usage of digital tools by women. For example, in Africa they represent almost one-half of the farming population but only one-quarter have registered to use digital apps. Similarly, 70% of registered users are considered to be youth, meaning that the older members of the population are not equally represented (Tsan et al., 2019). It should be realised that digital solutions will not be a panacea for all the challenges being faced by smallholder farmers. It was estimated that only 42% of farmers in Africa who registered their digital solution used it. The number of highly active users is more likely to be only between 15 and 30% (Tsan et al., 2019). So having the technology available is a good start, but it's then important to build a groundswell of active users.

FUTURE DEVELOPMENTS

Developers of digital solutions are tending to either create specialised, best-of-breed solutions to address a specific pain point for farmers, or create platforms that bundle several services together which meet a variety of pain points for farmers. Either way, they need to ensure that the solution aligns with human centred design principles. As the distribution of mobile phones and internet access by smallholder farmers continues to increase, the next challenge will be to increase the use of digital tools by farmers. This will involve improving the digital capability of the advisors, farmers and other key players in the system, so that they can make the most of the opportunity (Tsan et al., 2019).

Partnerships with mobile network operators and mobile money providers can assist with scaling the solutions through bundling and cross-selling services. Pay-as-you-go and other flexible payment options are allowing smallholder farmers to access equipment such as drones without the need for large upfront payments. As the needs of these users change over time, it is important that the technology providers remain agile and flexible, so as to meet the shifting needs of farmers (Phatty-Jobe et al., 2020).

According to Tsan et al. (2019) the future trends are likely to include:

- **Continued improvement in the enablers for digital agriculture including improved connectivity and mobile phone access, and expansion of digital payments.**
- **Increased adoption and use of innovative technologies including remote sensing, IoT sensors and diagnostic solutions.**
- **Accelerated business model innovation, especially those focusing on smallholder value chains. This includes market linkage services, bundled services and super platforms that can connect farmers with markets.**
- **Agricultural data and the growth in its use, availability and affordability, and corresponding growth in data analytics delivering more precise and real-time solutions.**
- **Increased investment in digital agricultural solutions by venture capitalists and large commercial companies.**

Another expected future trend is the increased usage of virtual reality (VR). This is an immersive, interactive computer-simulated experience, as if the user is in a different world. The equipment required is a headset, a handheld controller and sometimes other equipment that allows you to be able to do things in the simulation. There are two types of headset—a standalone headset (which does not have to be connected to another device), and a PC-based headset (which connects to a computer via a long cable). While still a relatively new field, there are some instances of this already being used in RAS activities (Karunasekera, 2011; Parikh et al., 2022; Strong et al., 2022).

A similar trend is the increased usage of augmented reality (AR). Unlike VR, this experience does not remove the user from their surroundings but instead overlays digital content around them in the real world so that it appears to be part of their environment. AR usually only requires a smartphone or tablet which helps visualise the 3D objects that are being superimposed into the surroundings (James, 2022). Again, while this is still a relatively new field, there are several instances of it already being used in RAS activities (Hurst et al., 2021; James, 2022; Katsaros & Keramopoulos, 2017; Sara et al., 2022; Xi et al., 2018).

CONCLUSION

It should be noted that people, not technology, are at the heart of the adoption of new digital technologies (Hansen et al., 2022) and their needs are what should drive the design and implementation of new technologies. These contemporary digital technologies continue to evolve and rapidly change, with new technologies becoming available almost daily. In the same way, the modern RAS professional also needs to continually change and build their capacity in these new technologies to support the farmers with whom they work. Support and resources need to be provided to assist extension practitioners to be trained in the appropriate use of these next generation extension tools and media (Chander & Rathod, 2020).

REFERENCES

- Aguilar-Gallegos, N., Klerkx, L., Romero-García, L. E., Martínez-González, E. G., & Aguilar-Ávila, J. (2021). Social network analysis of spreading and exchanging information on Twitter: the case of an agricultural research and education centre in Mexico. The Journal of Agricultural Education and Extension, 1-22. https://doi.org/10.1080/1389224X.2021.1915829

- Ahmadi, A., Ansyor, A., Suharyanto, S., & Hidayat, Z. (2021). Effectiveness of Digital-Based Agricultural Extension Implementation in Central Bangka Regency. E3S Web of Conferences, Aker, J. C. (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. Agricultural Economics, 42(6), 631-647.

- Aker, J. C., Ghosh, I., & Burrell, J. (2016). The promise (and pitfalls) of ICT for agriculture initiatives. Agricultural Economics, 47(S1), 35-48.

- Alam, M. M., & Shaba, S. A. (2022). ICT-enabled agricultural extension: How to promote and sustain? Information Development, 0(0), 02666669221112367. https://doi.org/10.1177/02666669221112367

- Anon. (2018). 8028 Farmer Hotline. Ethiopian ATA. http://www.ata.gov.et/programs/highlighted-deliverables/8028-farmer-hotline/

- Anon. (2022). Digital around the world. DataReportal. https://datareportal.com/global-digital-overview.

- Asenso-Okyere, K., & Mekonnen, D. A. (2012). The importance of ICTs in the provision of information for improving agricultural productivity and rural incomes in Africa. African Human Development Report. UNDP Sponsored research Series.

- Baffoe-Bonnie, A., Martin, D. T., & Mrema, F. (2021). Agricultural extension and advisory services strategies during COVID-19 lockdown. Agricultural & Environmental Letters, 6(4), e20056.

- Barbosa, J. Z., Prior, S. A., Pedreira, G. Q., Motta, A. C. V., Poggere, G. C., & Goularte, G. D. (2020). Global trends in apps for agriculture. Multi-Science Journal, 3(1), 16-20.

- Baul, T., Karlan, D., Toyama, K., & Vasilaky, K. (2020). Improving Smallholder Agriculture via Video-Based Group Extension. https://www.digitalgreen.org/wp-content/uploads/2017/06/Digital_Green-JPAL-11-28-20.pdf

- Benson, T. (2022). ICT Supported, Agricultural Extension and Advisory Services in Ethiopia.

- Bhattacharjee, S., & Raj, S. (2016). Social media: Shaping the future of agricultural extension and advisory services. GFRAS interest group on ICT4RAS discussion paper, GFRAS: Lindau, Switzerland, 9.

- Blackburn, S., & Gartner, D. (2017). Digital Australia: Seizing the opportunity from the fourth industrial revolution. Retrieved from https://apo.org.au/node/241111

- Chander, M., & Rathod, P. (2020). Reorienting priorities of extension and advisory services in India during and post COVID-19 pandemic: a review. Indian Journal of Extension Education, 56(3), 1-9.

- Chen, K., Leclair, M., Karamidehkordi, E., Larsen, C., & Babu, S. (2020). Extension and advisory services role in the COVID-19 crisis. https://agrilinks.org/post/extension-and-advisory-services-role-covid-19-crisis

- Christiaensen, L., Rutledge, Z., & Taylor, J. E. (2021). The future of work in agri-food. Food Policy, 99, 101963.

- Christoplos, I. (2010). Mobilizing the potential of rural and agricultural extension. Rome: FAO

- Cole, S., & Fernando, A. N. (2012). The value of advice: Evidence from mobile phone-based agricultural extension. Harvard Business School working paper #13-047.

- Cole, S. A., & Fernando, A. N. (2021). 'Mobile'izing agricultural advice technology adoption diffusion and sustainability. The Economic Journal, 131(633), 192-219.

- Cook, B. R., Satizábal, P., & Curnow, J. (2021). Humanising agricultural extension: A review. World Development, 140, 105337. https://doi.org/https://doi.org/10.1016/j.worlddev.2020.105337

- Cook, S., Jackson, E., & Cammarano, D. (2022). Global adoption of digital agriculture. Annales des Mines, September(19), 139-147.

- Cook, S., Jackson, E. L., & Baker, D. (2022). Digital Agriculture: A Tale of Unrealised Expectations? The Australian Farmer. https://www.theaustralianfarmer.com/digital-agriculture-a-tale-of-unrealised-expectations

- Davis, K., Bohn, A., Franzel, S., Blum, M., Rieckmann, U., Raj, S., Hussein, K., & Ernst, N. (2018). What Works in Rural Advisory Services? Global Good Practice Notes. Lausanne, Switzerland: GFRAS.

- Davis, K., & Sulaiman, R. (2016). Overview of Extension Philosophies and Methods. Note 0. GFRAS Good Practice Notes for Extension and Advisory Services. Lausanne, Switzerland.: GFRAS Retrieved from https://www.g-fras.org/en/good-practice-notes/0-overview-of-extension-philosophies-and-methods.html

- Drewry, J. L., Shutske, J. M., Trechter, D., & Luck, B. D. (2022). Assessment of Digital Technology Adoption and Access Barriers Among Agricultural Service Providers and Agricultural Extension Professionals. Journal of agricultural safety and health, 0(0), 0. https://doi.org/https://doi.org/10.13031/ja.15018

- Eastwood, C., Dela Rue, B., Edwards, J. P., & Jago, J. (2022). Responsible robotics design–A systems approach to developing design guides for robotics in pasture-grazed dairy farming. Frontiers in Robotics and AI, 1-9.

- Ewing Marion Kauffman Foundation, Morelix, A., & Russell-Fritch, J. (2017). Kauffman Index 2017: Growth Entrepreneurship State Trends. https://dx.doi.org/10.2139/ssrn.3080709

- Fabregas, R., Harigaya, T., Kremer, M., & Ramrattan, R. (2023). Digital Agricultural Extension for Development. In T. Madon, A. J. Gadgil, R. Anderson, L. Casaburi, K. Lee, & A. Rezaee (Eds.), Introduction to Development Engineering: A Framework with Applications from the Field (pp. 187-219). Springer International Publishing. https://doi.org/10.1007/978-3-030-86065-3_8

- Fabregas, R., Kremer, M., Lowes, M., On, R., & Zane, G. (2019). SMS-extension and farmer behavior: lessons from six RCTs in East Africa. Online at: https://www. atai-research. org/wp-content/uploads/2020/05/textfarmers1. pdf.

- Fabregas, R., Kremer, M., & Schilbach, F. (2019). Realizing the potential of digital development: The case of agricultural advice. Science, 366(6471), 1328. https://doi.org/10.1126/science.aay3038

- FAO, & ITU. (2022). Status of digital agriculture in 47 sub-Saharan African countries. Rome.

- Feder, G. (2005). The challenges facing agricultural extension-and a new opportunity. New Agriculturist, 2.

- Ferdinand, T., Illick-Frank, E., Postema, L., Stephenson, J., Rose, A., Petrovic, D., Migisha, C., Fara, K., Zebiak, S., & Siantonas, T. (2021). A Blueprint for Digital Climate-Informed Advisory Services: Building the Resilience of 300 Million Small-Scale Producers by 2030.

- Fernando, A. N. (2021). Seeking the treated: The impact of mobile extension on farmer information exchange in India. Journal of Development Economics, 153, 102713.

- Fernando, A. N., & Yaseen, R. (2022). Digital agricultural extension: Stimulating or supplanting farmers' interactions? Ideas for India. https://www.ideasforindia.in/topics/agriculture/digital-agricultural-extension-stimulating-or-supplanting-farmers-interactions.html

- Fielke, S., Taylor, B., & Jakku, E. (2020). Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. Agricultural Systems, 180, 102763.

- Fu, X., & Akter, S. (2016). The impact of mobile phone technology on agricultural extension services delivery: Evidence from India. The Journal of development studies, 52(11), 1561-1576.

- Gabrillo, C. A., & Torres, C. S. (2022). Perceived benefits of ICT-based rice technologies by farmers and agricultural extension workers. Journal of Agriculture and Technology Management, 25(1). http://jatm.ctu.edu.ph/index.php/jatm/article/view/485

- Gandhi, R., Veeraraghavan, R., Toyama, K., & Ramprasad, V. (2009). Digital Green: Participatory Video and Mediated Instruction for Agricultural Extension. Information technologies and international development, 5(1), 1-15.

- Hansen, B., Leonard, E., Mitchell, M., Easton, J., Shariati, N., Mortlock, M., Schaefer, M., & Lamb, D. (2022). Current status of and future opportunities for digital agriculture in Australia. Crop and Pasture Science.

- Hurst, W., Mendoza, F. R., & Tekinerdogan, B. (2021). Augmented Reality in Precision Farming: Concepts and Applications. Smart Cities, 4(4), 1454-1468.

- International Labour Organization. (2020). ILO Monitor: COVID-19 and the world of work. Fifth edition. Updated estimates and analysis. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/briefingnote/wcms_749399.pdf

- International Telecommunications Union. (2021). Measuring digital development. Facts and figures 2021. Geneva, Switzerland: ITU Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2021.pdf

- International Trade Centre Amsterdam and University of Applied Sciences. (2020). Business and policy insights: Mapping e-Marketplaces in Africa. Geneva: ITC
- James, J. (2010). Using Web 2.0 technologies to enable practice change in Australian agriculture. Extension Farming Systems, 5(1), 167-172.
- James, J. (2022). Using VR and AR in extension to add an extra dimension. Enablers of Change. https://www.enablersofchange.com.au/using-vr-and-ar-in-extension-to-add-an-extra-dimension/
- James, J., & Raj, S. (2021). e-Extension for extension professionals (NELK Themetatic 6). GFRAS Retrieved from https://www.g-fras.org/en/knowledge/new-extensionist-learning-kit-nelk
- Jarial, S., & Sachan, S. (2021). Digital agriculture through extension advisory services-is it gender-responsive? a review. International Journal of Agricultural Extension, 9(3), 559-566.
- Kaegi, S. (2015). The experiences of India's agricultural extension system in reaching a large number of farmers with rural advisory services. Background paper for Workshop Reaching the Millions, Hanoi, Vietnam.
- Kamath, R. (2018). Food traceability on blockchain: Walmart's pork and mango pilots with IBM. The Journal of the British Blockchain Association, 1(1), 3712.
- Kansiime, M. K., Alawy, A., Allen, C., Subharwal, M., Jadhav, A., & Parr, M. (2019). Effectiveness of mobile agri-advisory service extension model: Evidence from Direct2Farm program in India. World development perspectives, 13, 25-33.
- Karunasekera, N. P. (2011). Effectiveness of virtual reality based immersive training for education of health professionals: a systematic review (Doctoral dissertation, University of Canterbury). Retrieved from https://ir.canterbury.ac.nz/bitstream/handle/10092/6721/Karunasekera_thesis.pdf;sequence=1
- Katsaros, A., & Keramopoulos, E. (2017). FarmAR, a farmer's augmented reality application based on semantic web. 2017 South Eastern European Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM).
- Khan, N. A., Qijie, G., Sertse, S. F., Nabi, M. N., & Khan, P. (2020). Farmers' use of mobile phone-based farm advisory services in Punjab, Pakistan. Information Development, 36(3), 390-402.
- Kirui, O. K., Okello, J. J., Nyikal, R. A., & Njiraini, G. W. (2013). Impact of mobile phone-based money transfer services in agriculture: Evidence from Kenya. Quarterly Journal of International Agriculture, 52(2), 141-162.
- Klerkx, L. (2021). Digital and virtual spaces as sites of extension and advisory services research: social media, gaming, and digitally integrated and augmented advice. The Journal of Agricultural Education and Extension, 27(3), 277-286. https://doi.org/10.1080/1389224X.2021.1934998
- Lowder, S. K., Sánchez, M. V., & Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? World Development, 142, 105455. https://doi.org/https://doi.org/10.1016/j.worlddev.2021.105455
- Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. World Development, 87, 16-29

- Manyika, J., Ramaswamy, S., Khanna, S., Sarrazin, H., Pinkus, G., Sethupathy, G., & Yaffe, A. (2015). Digital America: A Tale of the Haves and Have-Mores.: McKinsey Global Institute Retrieved from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/digital-america-a-tale-of-the-haves-and-have-mores

- McCampbell, M., Schumann, C., & Klerkx, L. (2021). Good intentions in complex realities: Challenges for designing responsibly in digital agriculture in low-income countries. Sociologia Ruralis.

- Meera, S. N. (2020). Blog 125- Is COVID crisis a tipping point for transformational changes in digital extension? AESA blog. https://www.aesanetwork.org/blog-125-is-covid-crisis-a-tipping-point-for-transformational-changes-in-digital-extension/

- Nagarajan, L., Muesembi, T., & Fernando, A. (2020). Review of Existing Last Mile Seed Delivery Models and Approaches. A Feed the Future Global Supporting Seed Systems for Development activity (S34D) report.

- Namisiko, P., & Aballo, M. (2013). Current status of e-agriculture and global trends: a survey conducted in TransNzoia County, Kenya. International Journal of Science and Research, 2(7), 2319-7064.

- Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. Applied Economic Perspectives and Policy, 42(1), 8-20.

- Ortiz-Crespo, B., Steinke, J., Quirós, C. F., van de Gevel, J., Daudi, H., Gaspar Mgimiloko, M., & van Etten, J. (2021). User-centred design of a digital advisory service: Enhancing public agricultural extension for sustainable intensification in Tanzania. International journal of agricultural sustainability, 19(5-6), 566-582.

- Parikh, T., Egendorf, S., Murray, I., Jamali, A., Yee, B., Lin, S., Cooper-Smith, K., Parker, B., Smiley, K., & Kao-Kniffin, J. (2022). Greening the Virtual Smart City: Accelerating Peer-to-Peer Learning in Urban Agriculture With Virtual Reality Environments. Front. Sustain. Cities, 3, 815937.

- Perez, S. (2020). Report: WhatsApp has seen a 40% increase in usage due to COVID-19 pandemic. TechCrunch. https://techcrunch.com/2020/03/26/report-whatsapp-has-seen-a-40-increase-in-usage-due-to-covid-19-pandemic/

- Phatty-Jobe, A., with Seth, A., & Norton, K. (2020). Digital agriculture maps: 2020. State of the sector in low and middle-income countries.

- Philbeck, T., & Davis, N. (2019). The fourth industrial revolution: Shaping a new era. Journal of international affairs, 72(1), 17-22.

- Raj, S. (2021). Evidence from India: Impact of mobile phone technology on the performance of agricultural extension services. Asian Journal of Multidimensional Research, 10(10), 498-504. https://doi.org/http://dx.doi.org/10.5958/2278-4853.2021.00850.8

- Raj, S., Sulaiman, R., Davis, K., & Suchiradipta, B. (2018). Navigating ICTs for extension and advisory services. In K. Davis, A. Bohn, S. Franzel, M. Blum, U. Rieckmann, S. Raj, K. Hussein, & N. Ernst (Eds.), What Works in Rural Advisory Services? Global Good Practice Notes. (pp. 85-90). Lausanne, Switzerland: GFRAS.

- Ray, P. P. (2017). Internet of things for smart agriculture: Technologies, practices and future direction. Journal of Ambient Intelligence and Smart Environments, 9, 395-420. https://doi.org/10.3233/AIS-170440
- Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. Journal of rural studies, 85, 79-90. https://doi.org/https://doi.org/10.1016/j.jrurstud.2021.05.003
- Roberts, K., & McIntosh, G. (2012). Use of mobile devices in extension and agricultural production-a case study. 16th Australian Agronomy Conference. Capturing opportunities and overcoming obstacles in Australian agronomy.
- Rukuni, M., Ruhode, E., & Mucheri, T. (2021). AgriTech Blueprint for Africa: Under the leadership of the Republic of Zimbabwe and Smart Africa.
- Sara, G., Todde, G., & Caria, M. (2022). Assessment of video see-through smart glasses for augmented reality to support technicians during milking machine maintenance. Scientific Reports, 12(1), 15729. https://doi.org/10.1038/s41598-022-20154-2
- Schulz, P., Prior, J., Kahn, L., & Hinch, G. (2021). Exploring the role of smartphone apps for livestock farmers: data management, extension and informed decision making. The Journal of Agricultural Education and Extension, 1-22.
- Schwab, K. (2016). The fourth industrial revolution. Crown Business.
- Shakhovskoy, M., Saab, W., & Colina, C. (2021). Agricultural “platforms” in a digital era: Defining the landscape. ISF Report. https://isfadvisors.org/wp-content/uploads/2021/03/ISF_RAFLL_Agricultural_Platforms_Report.pdf
- Shepherd, M., Turner, J. A., Small, B., & Wheeler, D. (2020). Priorities for science to overcome hurdles thwarting the full promise of the ‘digital agriculture’ revolution. Journal of the Science of Food and Agriculture, 100(14), 5083-5092.
- Siankwilimba, E., Hiddlestone-Mumford, J., Hang'ombe, M., Mumba, C., & Hoque, E. (2022). COVID-19 and the Sustainability of Agricultural Extension Models. International Journal of Biological and Chemical Sciences, 1-20.
- Steen, M. (2012). Human-centered design as a fragile encounter. Design Issues, 28(1), 72-80.
- Stilgoe, J., Owen, R., & Macnaghten, P. (2020). Developing a framework for responsible innovation. In The Ethics of Nanotechnology, Geoengineering and Clean Energy (pp. 347-359). Routledge.
- Strong, R., Zoller, J., & Palmer III, J. M. (2022). Evaluating the Adoption of Virtual Reality Equine Selection and Judging Curricula: Instructional Responses to a COVID-19 Consequence. Journal of International Agricultural and Extension Education, 29(1), 76-85.
- Team Digital Green. (2022). Reaching more farmers through IVR. Digital Green. https://www.digitalgreen.org/blogs/reaching-more-farmers-through-ivr/

- Terazono, E. (2020). Vertical farming: hope or hype? Financial Times. https://www.ft.com/content/0e3aafca-2170-4552-9ade-68177784446e

- TNN. (2022, 27/9/2022). Agricultural information systems continue to fail women—videos centering women can make a difference. The Times of India,. https://timesofindia.indiatimes.com/education/news/agricultural-information-systems-continue-to-fail-womenvideos-centering-women-can-make-a-difference/articleshow/94486930.cms

- Tsan, M., Totapally, S., Hailu, M., & Addom, B. K. (2019). The digitalisation of African agriculture report 2018–2019. CTA.

- United Nations. (2021). COVID-19 and e-commerce a global review Retrieved from https://unctad.org/webflyer/covid-19-and-e-commerce-global-review

- Van Campenhout, B. (2017). There is an app for that? The impact of community knowledge workers in Uganda. Information, Communication & Society, 20(4), 530-550.

- Vedeld, T., Mathur, M., & Bharti, N. (2019). How can co-creation improve the engagement of farmers in weather and climate services (WCS) in India. Climate Services, 15, 100103. https://doi.org/10.1016/j.cliser.2019.100103

- Von Schomberg, R. (2011). Towards responsible research and innovation in the information and communication technologies and security technologies fields. Available at SSRN 2436399.

- Wise, J. (2022). Zoom Statistics 2022: How Many People Use Zoom? (NEW). EarthWeb. https://earthweb.com/zoom-statistics/

- World Bank. (2017). ICT in Agriculture (updated edition): Connecting Smallholders to Knowledge, Networks, and Institutions. Washington, DC: World Bank Retrieved from https://openknowledge.worldbank.org/handle/10986/27526

- World Bank. (2020). Poverty and Shared Prosperity 2020: Reversals of Fortune. Washington, DC: World Bank Group Retrieved from https://www.worldbank.org/en/publication/poverty-and-shared-prosperity

- World Bank. (2022). Understanding Poverty: Agriculture and Food https://www.worldbank.org/en/topic/agriculture/overview

- World Economic Forum. (2018). Innovation with a purpose: The role of technology innovation in accelerating food systems transformation. Retrieved from https://www3.weforum.org/docs/WEF_Innovation_with_a_Purpose_VF-reduced.pdf

- Xi, M., Adcock, M., & McCulloch, J. (2018). Future agriculture farm management using augmented reality. 2018 IEEE Workshop on Augmented and Virtual Realities for Good (VAR4Good).

- yahoo!Finance. (2022). Digital Agriculture Market worth $29.8 billion by 2027. https://finance.yahoo.com/news/digital-agriculture-market-worth-29-123000949.html

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