Emerging Technologies and the Agrarian Sector in Zimbabwe: Prospects and Challenges

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Abstract
Information Communication Technology (ICT) has been a significant contributor to the growth and socio-economic development in countries and sectors where they are well deployed. Innovative ICT's range from computers, radio, television and mobile phones to advanced technologies such as blockchain, artificial intelligence, cloud computing, Internet of Things and big data analytics are among the current trends. The study adopted extant qualitative paradigm to generate information. Research findings indicates that, Zimbabwe is prone to shocks that affect agricultural and livestock production, including extreme weather events, inflation, and external geopolitical conflicts. However, there are opportunities for boosting agricultural productivity in the agriculture sector in Zimbabwe making use of ICT tools and agriculture is expected to be a trillion-dollar industry by 2030 if these tools are fully embraced. Despite milestones achieved of ICTs adoption in the agricultural sector in Zimbabwe such as microfinance and mobile banking, mobile phones and radio, there exist a gap between small holder farmers, communal farmers and commercial farmers. Commercial farmers are fast adopting emerging technologies whilst small holder farmers and communal farmers are faced with challenges which include lack of security of land to access loans, high cost of data and low capacity, among other challenges. To promote innovation and growth of digital agriculture solutions, the government of Zimbabwe could consider enacting tax incentives for companies and organisations developing services that drive rural adoption, especially among farmers and other agricultural value chain actors.
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Key words: Agriculture, Information Communication Technology, Artificial Intelligence, Nanotechnology, Sensors, Drones

Introduction
Information Communication Technology (ICT) has been a significant contributor to the growth and socio-economic development in countries and sectors where they are well deployed. The effective integration of ICT in the agriculture sector in American and European countries has led to tremendous improvement in agriculture value chain efficiency and productivity (Ayima, Kassahunb, Tekinerdogan & Addison, 2020:1). ICTs may result in profound impacts on efficiency, resilience, and inclusion, while for developed nations, innovations are critical aspects of agricultural sector revolutionisation (Matsvai & Hosu, 2024:2). Innovative ICT's ranges from computers, radio, television and mobile phones to advanced technologies such as blockchain, artificial intelligence, cloud computing, Internet of Things (IoT) and big data analytics are among the current trends (Oxford Business Group, 2021:18). Through precision agriculture, farmers are able to engage in yield monitoring, soil mapping, crop health

monitoring, automated irrigation and crop planning and management. As a result of ICTs, enabled precision agriculture, productivity, cost saving, resource efficiency, environmental sustainability, quality agricultural decisions, climate change adaptation, targeted interventions, and efficiency will ultimately increase through ICTs (Matsvai & Hosu, 2024:3).

The agriculture sector in Africa is less developed and food insecurity is still a challenge. Though the continent has enormous natural resources, and the agricultural potential is high, many countries are still net importers of food. The continent imports about US$25 billion worth of food crops annually and the level of value addition and processing of agricultural commodities is also low and post-harvest losses are high (Ayim, et al., 2022:2). In addition, the challenge of climate change has resulted in an urgent desire to reconstruct the way food sufficiency is projected in Africa. Ensuring food security amidst a changing climate should be a top priority for policy advancement in Africa (Adeniran & Aristide, 2020:4). Yet, agriculture remains a significant sector within the continent. The agriculture sector accounts for almost two-thirds of the total employment and about 75% of domestic trade (Ayima et al., 2020:1). In this regard, ICTs have the potential to revolutionize agriculture in Africa, offering a myriad of benefits to farmers and stakeholders across the entire agricultural value chain (Kateule & Ghneim-Herrera, 2024:1). Africa governments have been leveraging digital tools and Mauritius, Uganda and Rwanda are using ICT solutions to update and improve their land information systems (Oxford Business Group, 2021:18). Moreover, professional farmers, and entrepreneurs in African agribusiness are advancing the adoption of ICTs as a strategy to fast-track improved yields in crop and animal production because of the increasing need to feed more people across Africa (Adeniran & Aristide, 2020:7)

In Zimbabwe, agriculture remains the engine of growth for the Zimbabwean economy; agriculture contributes roughly 17 percent to Zimbabwe's GDP, supplies 60 percent of the raw materials required by the industrial sector, and contributes 40 percent of total export earnings. About 33 million out of the country's 39 million hectares are used for agricultural purposes. Despite the country's extensive availability of agricultural land, Zimbabwe is a net importer of food (USAID, 2023:13). It is in retrospect of the shambles of the "fast track land reform" that the demise of the country's agricultural performance understated the true importance and dominance of the agricultural industry, in a country that was formerly the breadbasket of SADC region (Chisango, 2017:8). Zimbabwe is also prone to shocks that affect agricultural and livestock production, including extreme weather events, inflation, and external geopolitical conflicts. The country ranks 15th on the Global Climate Risk Index and is projected to face increased warming, a reduction in rainfall, and an increased frequency and intensity of tropical storms, floods, and droughts. As most of Zimbabwe's population depends on rain-fed agriculture, the trend towards low and erratic rainfall will pose challenges to the sector (USAID, 2023:14).

However, there are opportunities for boosting agricultural productivity in the agriculture sector in Zimbabwe making use of ICT tools and agriculture is expected to be a trillion-dollar industry by 2030 if these tools are fully embraced (Musungwini, 2018). Farmers in Zimbabwe are generally categorised based on the size and scale of their agricultural activities. The country has over seven million Small Holder Farmers (SHFs) and communal farmers. SHFs mainly use traditional farming methods, have small plots of land, and supply roughly 60 percent of the country's food. Communal farmers cultivate land in communal areas of the country, where the land is owned and managed by the state in consultation with the traditional leaders in the area. There are approximately 50,000 medium- to large-scale commercial farmers who operate larger farms and use advanced farming technologies and equipment (USAID, 2023:14). This entails that the application of ICTs has to be adopted by all Zimbabwean farmers to improve farming efficiencies.

Apparently, in this present age of globalisation, digital divide is continually widening between the developing and developed nations as farming and agricultural technologies in African countries like Zimbabwe is still lagging behind particularly in terms of ICT implementation (Parwada & Marufu, 2023:33; Chisango, 2017:9). This therefore presents the backdrop upon which this study that sought to assess emerging technologies in the agrarian sector in Zimbabwe and analysing their prospects and challenges. The study adopts extant qualitative literature to gather information. This study is structured into three sections, and these include methodological approach, research findings and analysis and conclusion and recommendations.

Research Methodology

Extant secondary qualitative paradigm was used to generate information. This approach was aimed to comprehend emerging technologies and their adoption in the agricultural sector, prospects and challenges associated ICT tools in Zimbabwe's agricultural sector. As a means of gathering specific and needed information, the analysis relied on secondary data from government publications in order to generate accurate data. More so, findings, conclusions and recommendations were also drawn from documentary search of books, journal articles, working papers and theses.

Results and Discussion

The main ICT tools being used in the agrarian sector in Zimbabwe

Microfinancing and mobile banking

In essence, access to finance has been well established as a major obstacle to the prosperity of many sectors of the economy, including the agricultural sector (Ssozi, Asongu & Amavilah, 2019). Innovations such as microfinance and mobile banking provide opportunities to boost African farmers' access to loans. As mobile penetration has increased in recent years in Africa, local entrepreneurs and international institutions have developed digital financial solutions aimed at supporting farmers (Oxford Business Group, 2021:6). From a theoretical angle, ICT improves financial sector development via improvement in the availability of credit to both households and firms, reduces asymmetric information between lenders and borrowers and boosts competition between financial sectors that is the formal and informal sectors (Asongu, 2020). In the process of enhancing financial intermediation and consolidating financial transactions, ICT can improve long term economic growth by means of better allocation of productive investments, and hence, increases agricultural sector development (Tchamyou, Erreygers & Cassimon, 2019).

Zimbabwe has a well-developed payments system, with 96 percent of transactions in the formal sector conducted digitally, which represents 40% of the economy. Financial transactions in Zimbabwe are led by mobile money providers, mainly Econet's EcoCash, NetOne's OneMoney, and Telecel's Telecash (Parwada & Marufu, 2023). TextaCash is another low-cost mobile money service operated by CABS, a financial institution in Zimbabwe. In May 2023, Old Mutual's fintech business "Old Mutual Digital Services" launched O'mari, a mobile wallet accessible via an application, WhatsApp, and USSD that encompasses mobile money transactions, bill pay, and grocery and school fee policies (USAID, 2023:24). In the agricultural sector, several demand side stakeholders accept farmer payments for inputs through these payment systems. For instance, Zimbabwe Super Seeds uses the CABS TextaCash platform for farmer transactions. Previously, many of their farmers were not banked, and the CABS TextaCash platform helped to open accounts and receive payments for their raw material supply to Zimbabwe Super Seeds. The cooperative is processing approximately US$1.5 million per year through the platform (USAID, 2023:35).

Mobile phones

Mobile phones are the widely used ICT tool within the agriculture sector (Ayima, et al., 2020:8). The proliferation of mobile phones within the African continent has led to the development of mobile-based applications and services within the sector. These services and applications are mostly targeted at farmers and provide a range of agricultural information such as market prices of farm produce, weather, agriculture input, and improved agriculture technique. Many agribusinesses use SMS and WhatsApp to answer questions received from SHFs and disseminate agronomy information (Owusu, Yankson, & Frimpong, 2017). There are three licensed mobile operators in Zimbabwe, the privately-owned Econet Wireless Zimbabwe and two government-owned operators, NetOne and Telecel Zimbabwe. Econet dominates the market with a 70 percent market share and an active subscriber base of almost ten million, and NetOne and Telecel sit in second and third place, respectively (USAID, 2023:22).

Currently, the agriculture in the Zimbabwean communal farmers is digitalised mainly through the use of cell phones to access farming information. The common digital agriculture innovations used in Zimbabwe include the Zimbabwe Farmers Union (ZFU) and Ecofarmer Combo programme and Econet Wireless championed. These avails weather-based insurance, farming advice for over 80,000 rural and communal farmers as well as real time location-based climate and weather information (Parwada & Marufu, 2023:34). The EcoFarmer mobile farming platform launched in 2013 by Econet Wireless is one of the earliest digital agriculture products providing information and extension services to farmers through the 144 toll-free line and *144# dial-in by Econet network users. NetOne also developed "Hurudza-Umlimi Omkhulu" accessed via *140# for farmers to subscribe and get access to diverse information in the farming ecosystem (USAID, 2023:25).

Radio

Radio is an important ICT tool in disseminating agriculture information to farmers. The radio remains the most widely used medium in rural areas in Zimbabwe (Hudson, Leclair, Pelletier & Sullivan, 2017). For instance, there exists multiple radio stations in the country which are interactive in nature and designed to help small-scale farmers to increase their production. Listenership is higher in rural areas where communal farmers and SHFs are located than in urban areas. Of the 2.3 million households with a radio, 1.3 million of them are in rural areas (USAID, 2023:22). The radio programmes include regular radio broadcasts on agricultural information to farmers. The programmes allow farmers to ask questions through SMS or by calling and the responses are disseminated via the radio (Ayima, et al., 2020:8). Radio Zimbabwe, the country's oldest and most popular radio station, has 47 percent listenership in rural areas compared to 28 percent in urban areas. Several development organisations interviewed have also disseminated agronomy information and best practices via the radio (USAID, 2023:22). The use of radio by most farmers is because the radio programmes are broadcasted on community radios and in the local language of the farmers making it easy for farmers to understand the content of the information (Ayima, et al., 2020:8).

Emerging technologies in the agrarian sector

There is a positive increase in the way digital agriculture is used but uptake of emerging technology is normally capital intensive for SHF and communal farmers in Zimbabwe and they remain a distant dream. These include blockchain, artificial intelligence (AI), cloud computing, nanotechnology, IoT and big data analytics, remote sensing using satellite technologies, and geographical information systems. Application of these technologies has been concentrated in few well financed commercial farms especially under management of large multinational companies (Shonhe & Scoones, 2022).

Artificial Intelligence (AI)

One of the most critical emerging disruptive digital technologies is AI (Zakaria and Hassan, 2023). AI is present wherever machines can perform tasks, using high levels of independent intelligence, that were typically done by humans. This machine intelligence is different from natural intelligence found in biological organisms as it is created, artificial, and digital. AI is a software that can initiate logical reasoning, learn, and solve complex problems (Ryan, Isakhanyan, & Tekinerdogan, 2023). AI in precision agriculture enables farmers and farm managers to deploy highly targeted and precise farming practices based on site-specific agroclimatic field measurements. AI can help farmers reduce errors and minimise crop failure risks by forecasting and predicting future events. A farmer can take advantage of global climate change to provide accurate and timely weather information that is favorable for planting during times of global climate change (Odume, 2024:60). With AI, producers, retailers, and most importantly farmers gain better insights into the whole value chain of agricultural inputs, resulting in a more transparent relationship between all parties (Zakaria and Hassan, 2023). AI can also help farmers monitor potential threats to agricultural productivity, for example, the occurrence of pests and disease which can be a difficult task to do manually, especially in large acreages (Parwada & Marufu, 2023:38). To add on, the use of predictive analytics, powered by AI is effective in predicting crop yield and future prices for agricultural commodities (Benos, Tagarakis, Dolias, Berruto, Kateris, & Bochtis, 2021).

Sensors

Precision agriculture relies on advanced technologies to enable accurate and timely management of agricultural processes. One of the key aspects of this practice is the integration of sensors, which collect data on various parameters of the environment and crop conditions (Bošković, Marina, Pajić & Subić, 2024:299). This data allows farmers to make timely decisions, optimise the use of resources such as water, fertilisers, and pesticides, and improve the overall efficiency of agricultural production. Sensors used in agriculture play a significant role in soil and plant growth and enable real-time physical and chemical interactions in the environment, such as temperature, moisture/humidity, pH, pests, and contaminant levels. Additionally, these sensors provide essential data that can enhance crop growth scenarios, resist biotic and abiotic stresses, and improve crop production (Faqir, Qayoom, Erasmus, Schutte-Smith & Visser, 2024:1). Integrating IoT connectivity into soil moisture, sensors can offer prognostic insights for water resource management and agricultural planning (Wang, Lin, Han, Fu, Huang, & Cheng, 2022). To add on, several potential techniques, such as acoustic sensors, nanostructured biosensors, optoelectronic sensors, electronic sensors, and impedance sensors, have been suggested for the identification of soil pests (Rhodes, Bennie, Spalding, French-Constant, & Maclean, 2022). Moreover, to determine the pH of soil, different sensors, including optical methods (such as colorimetric or photometric approaches), electrochemical methods (such as conductometric and potentiometric systems), and acoustic systems, are used (Neina, 2019).

Nanotechnology

Nontechnology deals with the matter at nano scale (1-100 nm) dimensions. These materials when reduced to the nano scale show some properties which are different from what they exhibit on a macro scale, enabling unique applications (Elizabath, Babychan, Mathew & Syriac, 2019:132). Nanotechnology opens a large scope of novel application in the fields of biotechnology and agricultural industries, because nanoparticles have unique physicochemical properties for instance, high surface area, high reactivity, tunable pore size, and particle morphology (Vangala, Das, Kumar, & Alazab, 2021). Nanoparticles can serve as magic bullets containing herbicides, nano-pesticide fertilizers, or genes, which target specific cellular organelles in plant to release their content (Elizabath, Babychan, Mathew & Syriac, 2019:131). Nano-biotechnological techniques can benefit diverse processes related to plant biology, including seed germination, plant growth enhancement, plant nutrition improvement, secondary metabolites isolation, and protection provision against biotic and abiotic stress factors (Domguia & Asongu, 2023). Nanotechnology presents significant opportunities for agriculture due to its typical physicochemical traits, such as substantial surface area, heightened reactivity, adjustable pore size, and particle shape (Al-RawI, Mohammed, Al-Taweel & Cheyed, 2024:1929). To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nano fertiliser might be a best alternative. Attempts have been made to synthesise nano fertiliser in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nano fertiliser are more efficient than ordinary fertiliser (Oxford Business Group, 2021:23).

Agricultural drones

Drones, also known as Unmanned Aerial Vehicles (UAVs), have evolved into integral technological devices that aid various human endeavors. Their applications span military uses, photography, transportation, sports and recreation, and notably, agriculture (Kwao, Owusu, Okyere, Agbenya, Laryea, & Armah, 2024:1). Ground-based and aerial-based drones are being used in agriculture in order to enhance various agricultural practices, that is, crop health assessment, irrigation, crop monitoring, crop spraying, planting, and soil and field analysis. From the drone data, farmers can draw insights regarding plant health indices, plant counting and yield prediction, plant height measurement, canopy cover mapping, scouting reports, stockpile measuring, chlorophyll measurement, nitrogen content in wheat, drainage mapping, weed and pressure mapping, among others (Kumar et al., 2023:26). Drones have proven to be transformative technologies in agriculture. The adoption of drones can lead to increased crop yields, efficient resource utilisation such as water and pesticides, and maximised farm productivity by offering innovative solutions to the challenges associated with conventional farming practices. These capabilities help save time and labor costs, improve resource management, enhance safety by reducing human exposure to hazardous chemicals, and combat climate change impacts (Kwao, Owusu, Okyere, Agbenya, Laryea, & Armah, 2024:1).

Geographic information systems

GIS is a powerful toolkit that can be used to store, retrieve, and alter spatial data for a variety of uses. The current advancements in GIS and Geographic Positioning Systems (GPS) technology offer a potential avenue for obtaining and implementing high-resolution satellite imagery and digital spatial data (Kumar et al., 2023:19). In the agricultural sector, its ability to analyse and illustrate agricultural settings and workflows has shown to be especially useful. A farm cannot be productive and successful unless its inputs and outputs are balanced (Mahanta, Prusty & Saha, 2024:287). Spatial data in the field of agriculture have been essential in examining the spatial connections between social, physical, agroecological, and environmental factors, and their impact on the sustainability of agricultural practices (Trivedi, Rao, Rajwade, Yadav & Verma, 2022). There are seven distinct application areas of GIS within the field of agriculture. These areas encompass crop yield estimation and forecasting, assessment of soil fertility, analysis of cropping patterns and agricultural monitoring, evaluation of drought conditions, detection and control of pests and crop diseases, implementation of precision agriculture techniques, and management of fertilisers and weeds (Raihan, 2024:5).

Prospects for adopting ICTs in agriculture

Strengthen coordination and collaboration

ICT tools strengthen the coordination and collaboration of farming communities with various institutions, non-governmental organisations, and private companies through its wide networking. Through the use of ICT, entrepreneurs can create new opportunities by penetrating international market and get contact with new partners and exchange relevant information for their business sustainability (Saidu, Clarkson, Mohammed & Jibo, 2017:12). For example, there is a limited supply of mechanisation access services in Zimbabwe. EcoFarmer's Vaya Tractor is one of the few platforms allowing farmers subscribed to Econet to hire, order, and pay for farming equipment via mobile phones by dialing *902#. Farming equipment available for hire on the platform includes tractors, rippers, sprayers, spreaders, planters and disc plows, harrows, and combine harvesters. Murimi 247 also has a mechanisation platform that aims to increase easy access to farm mechanisation solutions by renting tractors and farm equipment for small and large farms. There are about 4,300 farmers who are active users, 50 percent of whom are women (USAID, 2023:27).

Access to information

In agriculture, the right decision at the right time is absolutely necessary. ICT plays an indispensable role in agricultural development to support the farmers. Farmers can access the weather, market and efficient mechanisms related to information in the agriculture sector for higher production through ICT (Kumar et al., 2023:22). To add on, the use of ICT provides likelihoods for younger generation-agro based entrepreneurs to establish their own network and websites regardless of time and place. Consequently, they could advertise their products both in national and international markets. Likewise, ICT solves issues such as traceability, process control, transparency in market information, reduction in transaction costs, and identification as well as tracking of consumer needs (Saidu, Clarkson, Mohammed & Jibo, 2017:11). For example, Econet Wireless also launched the Ownai Online Marketplace, one of Zimbabwe's dominant marketplace platforms. Another offering comes from its sister company, EcoCash Holdings, where subscribing farmers can access an Ecofarmer Club Trading platform to sell crops and livestock via a USSD channel. Murimi 247 also offers an online store that links farmers to certified inputs suppliers who are pre-vetted by experts to ensure the farmer does not buy counterfeit inputs (USAID, 2023:27).

Reduce farmer's risk

Farmers are always at high risk in agriculture. Due to climate change, most of the smallholder farmers do not have enough resources and capacity to cope with climatic shocks which reduces agricultural productivity. These farmers have to face various risks in agriculture including new disease and pest outbreaks, adverse weather conditions and other risks (Kumar et al., 2023:22). Due to climate change, most of the smallholder farmers do not have enough resources and capacity to cope with climatic shocks which reduces agricultural productivity (Raihan, 2024:5). These farmers have to face various risks in agriculture including new disease and pest outbreaks, adverse weather conditions and other risks (Domguia & Asongu, 2023). The agricultural information that are applied in the local communities about the climate and soil properties help farmers in identifying opportunities and reduction of risks that are associated with changes occurring in their land. Moreover, emerging technologies such as AI can help farmers reduce errors and minimise crop failure risks by forecasting and predicting future events. AI can provide and timely weather information that is favorable for planting during times of global climate change (Odume, 2024:60).

Challenges of adopting ICTs in the agricultural sector in Zimbabwe

Digital infrastructure and adoption deficit

The infrastructure needed to effectively use ICTs in agriculture is often lacking (Kateule & Ghneim-Herrera, 2024:5). ICT infrastructure is mostly limited to urban areas in Zimbabwe while the rural areas remain beyond the ambit of new technology (Nyakudya, Jambo, Madududu & Manyise, 2024:8). This situation is made deleterious due to unsuitable ICT policies, specifically those that address rural communities and their growth, lack of sustainability because most ICT initiatives are project-based, disjointed and uncoordinated. Poor implementation of policies that support of ICT infrastructure in rural communities is among the key impediments to wider usage by small-scale and rural farmers (Saidu, Clarkson, Mohammed & Jibo, 2017:14). To add on, most of the emerging technologies requires High Performance Computing (HPC). In Zimbabwe there is only one HPC located in Harare which is only used for academic purposes called Zimbabwe Centre for High Performance Computing. The unavailability or restrictions of HPC means that machine learning operations are limited and crippled (Parwada & Marufu, 2023:39).

Poor connectivity and power supply

Although mobile network coverage is increasing, some rural areas still do not have connectivity and access to the internet (Kateule & Ghneim-Herrera, 2024:5). The lack of reliable and affordable internet connectivity remains a key barrier to inclusive digital growth in Zimbabwe. The average cost per one gigabyte of mobile data is US$4.26. Additionally, Zimbabwe is the third-most expensive country in the world in terms of monthly average broadband cost (USAID, 2023:15). SeedCo, an agribusiness that uses virtual platforms for field days and virtual field tours to educate their customers, has often failed to run the platforms due to poor connectivity (USAID, 2023:40). The most significant challenge most farmers face is the electricity shortage. Zimbabwe experiences frequent load-shedding, so farmers resort to traditional methods in their production processes. In such instances, farmers may be unable to access critical agricultural information, reducing their chances of achieving their goals and objectives (Nyakudya et al., 2024:8).

Low capacity

Many SHFs have limited knowledge and capacity to use digital tools, especially older farmers. Old farmers are often resistant to change, especially adopting innovative technology because they are unfamiliar with it (Nyakudya et al., 2024:10). Technology is a very alien concept to SHF and communal farmers in Zimbabwe and their line of work is generally slow and simple and does not rely on any computers. Most of these farmers have never even used a computer in their lives and they may not have the knowledge or skill set to use the available ICT tools that aid in digital farming (Parwada & Marufu, 2023:39). The low digital literacy levels have resulted in a mismatch between the technology available on the market, and what farmers understand and can use. This mismatch is compounded by low smartphone device ownership and access to affordable smartphone devices by rural farmers (USAID, 2023:39). Low capacity by SHF and communal farmers in making use of ICT tools in Zimbabwe prohibits these groups of farmers from accessing new information, knowledge, skills and technology that could be useful in boosting productivity. The prevailing scenario keeps the farmers at bay and widens the gap of their isolation from economic and technological change (Chisango, 2017:9).

Stringent ICT policies

Agriculture development in Zimbabwe has been undermined by poor policies that constrain market entry and the effective allocation of resources. Poor prioritisation of ICT initiatives, weak monitoring, poor implementation and integration of ICTs within the agricultural sector are due to poor ICT policies (Ayima, et al., 2020:12). Moreover, the collection and storage of sensitive information such as farm locations, crop yields, and financial data pose risks of unauthorised access and misuse, creating a reluctance among farmers to adopt these technologies (Kateule & Ghneim-Herrera, 2024:6). To add on, copyright and privacy concerns images and data obtained from drones tends to give rise to privacy issues especially when training with these images. Already existing laws on copyright, privacy and data protection laws hinder farmers from using drones and satellite images for smart farming. In Zimbabwe one needs a drone license in order to operate a drone. The approval of the drone to a farmer depends on the nature of justification the farmer can produce so as not to infringe on privacy rights. The drones are dependent on the provided dataset. It is difficult to come up with the dataset if the license has not been approved so it is a challenge coming up with the dataset which will not be copyrighted at the moment (Parwada & Marufu, 2023:39).

Security of land

The revolutionary impact of ICTs on the agriculture sector is spreading throughout Africa. In some parts of Africa this was kicked off with land reform, which is a core requirement in food and animal production. Security of land is especially crucial for SHF and communal farmers (Adeniran & Aristide, 2020:10). In Zimbabwe however, one of the key factors perpetuating the relatively low levels of cultivated land is the challenge of obtaining access to title deeds in the first place (Oxford Business Group, 2021:6). Farmers are underfunded due to mainly lack of property rights or title deeds to surrender to financing institutions as collateral, farmers therefore resort to extensive peasantry practices which fuel low productivity as farmers salvage paltry output levels not even adequate to meet family consumption requirements hence failing to afford ICT tools (Chisango, 2017:9). Stanbic Bank offers agricultural input financing, mainly for commercial tobacco farmers, and asset financing for agricultural equipment. Tobacco loans have a period of 14 months with USD interest rates of 12 percent. Commercial Bank Zimbabwe (CBZ) also provides input loans to 1,300 SHFs and 600 commercial farmers and conducts its own credit assessments. There is no collateral required for existing and returning customers, but new customers must show title deeds or commercial properties in their name as a form of collateral security (USAID, 2023:29).

Lack of funds to invest in ICT tools in agriculture

Difficulty accessing capital is one of the major challenges faced by agri-businesses in Zimbabwe. Commercial loans are expensive, and most businesses operating in the sector are small and medium-sized enterprises with little collateral (Oxford Business Group, 2021:10). Access to finance is a challenge, especially for the majority of SHFs who do not have the immovable collateral that is required by the banks for lending. The current funding mechanisms are mainly short-term seasonal funding which often comes at a very high cost. Given the prevailing economic environment in Zimbabwe and the lack of access to finance, technologies such as precision agriculture technology, which require a substantial investment, remain inaccessible to small-scale farmers (USAID, 2023:39). Suppliers of precision agriculture advisory services focus on commercial farmers. Suppliers of these services have determined that serving SHFs can be too complex given the high costs associated with equipment procurement and infrastructure needed to operationalise the equipment, and the limited ability and willingness of SHFs to pay (Kateule & Ghneim-Herrera, 2024:5). For example, the minimum viable area for Alley Capital Group to travel to and offer their services is ten hectares, which is often larger than the land that SHFs cultivate. GPS-fitted tractors supplied by Bain New Holland come with a software subscription fee of US$1,400 to US$1,700 per year, which is often beyond the reach of SHFs (USAID, 2023:26).

Conclusion and recommendations

The study analysed emerging technologies and the agrarian sector in Zimbabwe looking at their prospects and challenges. The study identified several ICT tools being ulitised in the agricultural sector and these include blockchain, AI, cloud computing, nanotechnology, IoT and big data analytics, remote sensing using satellite technologies, and geographical information systems. Application of these technologies has been concentrated in few well financed commercial farms especially under management of large multinational companies. SHF commonly make use of microfinance and mobile banking, mobile phones and radio. Notwithstanding the positive strides in ICT adoption, it can be concluded that the agricultural sector is faced with challenges related to adoption of ICT tools and these includes digital infrastructure and adoption deficit, poor connectivity and power supply, low capacity, stringent ICT policies, security of land and lack of funds to invest in ICT tools in agriculture.

It is, therefore, recommended that the governments should create facilities for the provision of economically viable agricultural financial services as this will empower farmers to acquire ICTs and modernise their farms. In addition, these measures could increase the indirect effect of ICTs on increasing agricultural production. Moreover, communal farming models are there to stay and remain a livelihood option for a majority of the rural Zimbabweans, it is therefore imperative that the aggregation of new technologies particularly ICTs would be an indispensable tool for empowering small scale agricultural farmers. To add on, key barriers to the adoption and usage of digital tools and services among rural farmers include connectivity challenges in rural areas and high internet costs hence it is imperative for agri-businesses to leverage offline digital solutions to disseminate content and information to farmers in remote areas of the country.

The issue of land security has to be addressed by the government. It is imperative that farmers are provided with title deeds so as to be able to access credit from financial institutions in order to boast their production to be profitable and hence afford ICT tools. Moreover, to promote innovation and growth of digital agriculture solutions, the government can consider enacting tax incentives for companies and organisations developing services that drive rural adoption, especially among farmers and other agricultural value chain actors. These tax incentives will motivate technology service providers to deploy digital technologies to unserved and underserved rural communities. To add on, implementing programmes that focus on building the capacity of SHFs on digital literacy and can help create awareness and build confidence in digital tools developed for the agriculture sector.

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