EPiC Series in Education Science
Volume 6, 2024, Pages 1–12
Proceedings of the NEMISA Digital Skills Summit and Colloquium 2024

Towards Sustainable Agriculture: The Opportunities and Challenges of Artificial Intelligence in Agricultural Advisory Services

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Abstract

Economic growth, employment creation and resilience of businesses and industry in the 4th Industrial Revolution which is intertwined with climate change realities depends much on the implementation of digital technologies and Artificial Intelligence (AI). The agricultural sector is no exception to these developmental realities. That is to say, the sector is equally compelled to implement AI in almost all the stages of agricultural production. From the cultivation of crops to transportation of the products to the target markets or the public. These will include having farmers and Extension Services implementing AI for crop yield detection, soil nutrients and moisture contents, climatic conditions predictions, milking and harvesting as well as weeds, pests and diseases identification and management. This paper explored the opportunities and challenges of AI in the implementation of Agricultural Advisory Services (AASs) for Sustainable Agriculture. These were achieved through extensive literature review which comprised of a conceptual framework for the implementation of AI in the AASs. The findings show the leveraging benefit of AI in the production costs among farmers, increase in farm productivity, and ease of access of AASs which was always almost a mission to achieve, especially, in the developing countries. Therefore, it is recommended that the relationship between youth participation in the agricultural sector and the implementation of AI and Digital Technology in the sector be explored, with the impact of the implementation of AI in the sector and the contribution of the sector towards developing countries' Gross Domestic Products (GDPs). The ethical implications of AI in AASs and the Agricultural Sector as a whole must be explored to unveil issues that may hamper the future acceptance of these digital skills and innovations.

1 Introduction

The growth witnessed in the agricultural sector necessitates the use of Artificial Intelligence (AI) in order to improve efficiency, effectiveness, and accuracy. Artificial Intelligence refers to a field in computer science that focuses on the development of machines to perform the same tasks usually required of Human Intelligence (HI) (Kumar, 2019 and Yadav *et al*., 2020). It is also viewed as a computerized ability to perform tasks usually performed by humankind, which then aids humankind to accomplish some tasks effectively and efficiently (timeously). The AI tools used in the sector varies from country to country, and with the type of farming practices and/or system, that is Commercial or Smallholder (Subsistence) farming (Kaushal *et al*., 2022). These include but not limited to drones for crop yield estimations, identification of pests, diseases, and weeds; environmental sensors for measuring of temperatures, humidity, and soil conditions; Unmanned Aerial Vehicles as well as the GPS auto steers for tractors in the farms (Trendov *et al*., 2019 and Sithole, 2020). These are essential for the very reason that the agricultural sector is labour intensive, and that reduces efficiency, effectiveness, and profitability (Kaushal *et al*., 2022). This then becomes an agricultural sustainability challenge. Hence, the need to use the AI tools to leverage the stress faced with farmers.

In recent years, projections on how the agricultural sector can extensively benefit from the use of AI have been increasing. This comes also with estimations of a 37.3% growth rate of the sector with the aid of the AI tools between 2020 – 2050 (Mekal *et al*., 2017; Bannerjee *et al*., 2018; Kaushal *et al*., 2022). Furthermore, this comes in the form of optimal pest control, soil health and moisture contents monitoring, analysis of data for farmers, and the production of high-quality crops (Trendov *et al*., 2019 and Sithole, 2020). The use of AI in the sector has also contributed towards enhancing the management of practices and activities within the agricultural value chain. This is evident that the use of AI contributes towards achieving sustainable agricultural goals and objectives (Sood *et al*., 2022 and Sharma *et al*., 2022). The sustainable agriculture goals and objectives that can best be achieved with the introduction of AI in the agricultural sector includes: 1. To satisfy the human needs for food and fibre, 2. To improve the environmental quality and natural resource base upon which the agricultural sector is dependent, 3. To efficiently use our non-renewable and non-farm resources, 4. To sustain the economic viability upon which the farm operations are dependent and 5. To improve the quality of life for both the farmers and society at large.

Primary agriculture is the main farming type where AI is used in the agricultural sector, with a market share of 60% (Trendov *et al*., 2019). This means it contributes a lot towards the development of farming practices and efficiency of farming activities (Kaushal *et al*., 2022). With the benefits (as listed above), that AI brings in the agricultural sector, AI comes with numerous ethical issues that affect the agricultural sector. This mainly is with regards to the use of information taken from others without their knowledge as well as authenticity of information, especially, information to smallholder farmers. Some other ethical issues of AI in the agricultural sector are the issues of farmer's privacy being invaded, levels of accountability are reduced, the welfare of animals is also threatened using robotics in the sector, accuracy, and reliability of the data set (Lokers *et al*., 2016 and Ryan *et al*., 2019). Moreover, the interesting part is that of the Agricultural Advisory Services (AASs) to farmers with the use or help of AI. Of course, researchers argue that AI will improve AAS delivery, efficiency, effectiveness, timeliness, and relevance of extension services across the world (Manivannan & Priyadharshini, 2016 and Talaviya *et al*., 2020). The benefits of using AI in AASs is evident, however, the ethical issues around the invasion of AI in the delivery of the AASs has not been established. It is envisioned that the use of AI in the delivery of AASs across the world will have to involve ChatGPT with a Chabot, which will afford farmers across the world access to AASs with ease and high degree of convenience.

This will improve access to AASs and reduce the costs of offering AASs to farmers. That includes transport and telephone costs. It is further envisioned that the future AASs will include Farm Radios (FR) to improve communication between Farmers and Agricultural Extension Advisors or Officers. The invasion of all these in extension, brings rise to concerns such as accountability, reliability of AI, farmers' privacy, fairness, equality, and confidentiality issues. All this is not yet established since the concept of AI in AASs is still new and at development stage. Therefore, the paper will explore the opportunities and challenges of AI in the delivery of AASs. This is achieved through systematic and extensive review of frameworks and concepts of Artificial Intelligence, Sustainable Agriculture as well as the ethical implications of AI in the delivery of Agricultural Extension Services.

1.1 Conceptual Framework

Figure 1, below, is the conceptual framework of the implementation of Artificial Intelligence (AI) in the Agricultural Extension Services, also known as Agricultural Advisory Services. The conceptual framework includes the AI tools and equipment, the human expertise required for the implementation of AI in the Agricultural Advisory Services as well as the ethical concerns around the implementation of AI in the AASs. It further shows the benefits of the implementation of AI in the agricultural sector. In accordance with Trendov *et al*., (2019) and Partel *et al*., (2019), the AI tools and equipment replaces the historically known as the agricultural manually operated tools and equipment. This is achieved through the introduction of remote sensors (also known as drones), intelligent spraying machines, automated milking machines, unmanned aerial machines and vehicles, and agricultural robots (Trendov *et al*., 2019; Sithole, 2020 and Talaviya *et al*., 2020).

On the other hand, AI requires some expertise in order efficiently and effectively operate and function. AI is a significantly increasing subject of discussion in many agricultural platforms. According to Channe *et al*., (2016); Talaviya *et al*., (2020); and Kaushal *et al*., (2022) AI is required in the agricultural sector so to ensure tracing, control, management, reasoning, testing and performance or productivity. All these are considered to be datasets collected in real time in order to enhance decision making processes in the agricultural value chain. In as much as AI is so beneficial for the sector, it has some ethical issues which the industry or sector is currently concerned about. These involves the accuracy and reliability of the datasets and information sources, it has not offered proof that information will be treated with strictness of confidentiality, fairness of the distribution of the data and time for each farmer has not been established as well as the quality of the datasets. As a matter of fact, Ngo *et al*., (2019) argues that use of AI for weeds detection in order to make informed decisions on weed control came with at least 70.5% accuracy level, while Sejaritha *et al*., (2017) postulated that weed detection in sugarcane came with at least 92.9% accuracy. Maruyama & Naruse (2014) postulated that weeds prevention robots by means of robots' movements in the field was recorded, however, level of3 accuracy was not confirmed. A similar incidence reported by Partel *et al*., (2019) asserting that weeds detection and control by means of precision weeds management systems was recorded but without accuracy levels. These are a few other ethical concerns which studies still need to unveil for the sector to be aware of and benefit from the information, knowledge, and skills that AI brings to the sector to enhance productivity.

A number of studies have reported the benefits of AI in the agricultural sector to include crop yield predictions, price forecasting, smart spraying, climate predictions, soil and crop monitoring, ease of milking through the use of milking robots, ease of weeds management through the use of weeding robots, ease of harvesting through the use of harvesting robots, pests and diseases management through use of robots, diagnosis and treatment of animal diseases through the use of disease diagnostic and treatment robots (Maruyama & Naruse, 2014; Trendov *et al*., 2019; Ngo *et al*., 2019; Talaviya *et al*., 2020 and Grover *et al*., 2022). These are further expounded on section 3.2 of this paper. In as much as AI can be viewed to come with a challenge of job opportunities, but many are the benefits of these systems to be forfeited by the sector in comparison to the job losses.

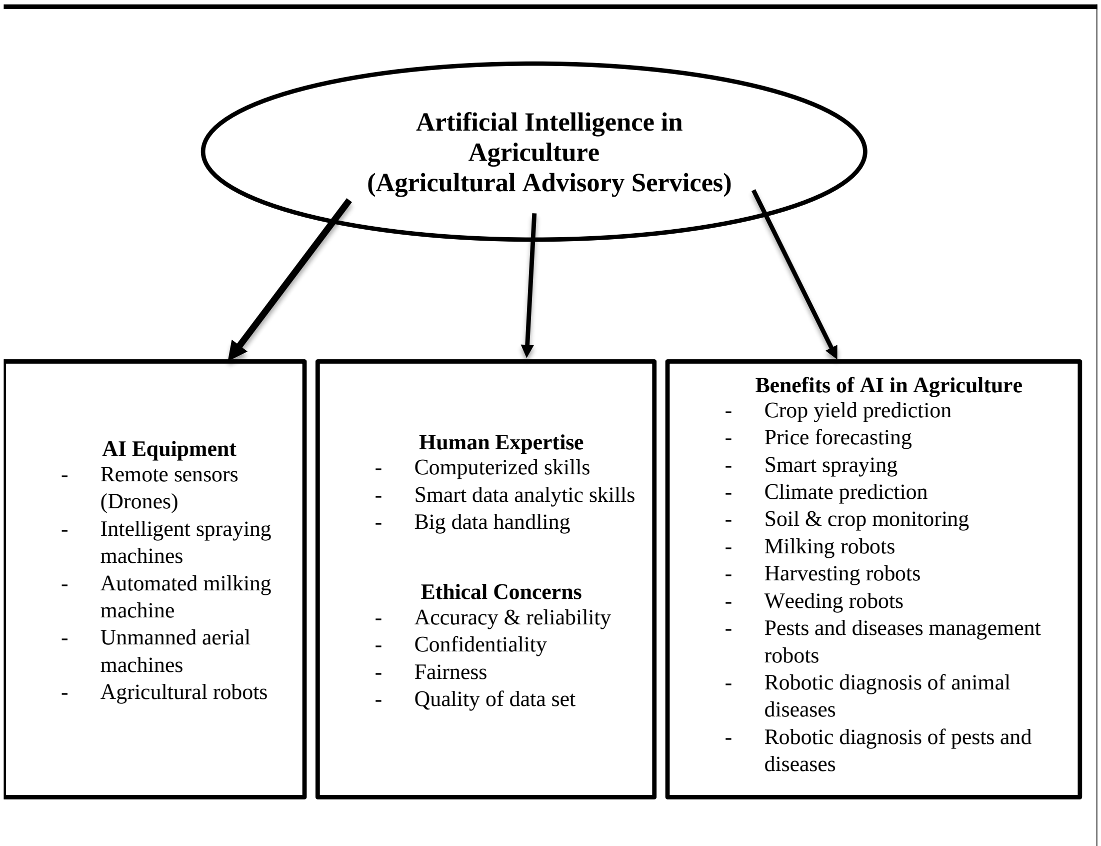

Figure 1: Conceptual Framework of Artificial Intelligence in Agricultural Extension Services

2 Methodology

This paper took the systematic approach to extensively review concepts, conceptual framework, opportunities, and challenges of Artificial Intelligence (AI) as a digital skill, particularly, for Agricultural Advisory Services. Journal articles, books and reports from various congress were reviewed extensively. These articles, books and reports were selected based on having dealt with the delineation of Artificial Intelligence (AI), the implications of AI in the Agricultural Extension Services (AESs), the dimensions of AI as well as the opportunities and challenges of AI for the AESs for achieving Sustainable Agriculture (SA). All other materials which were not published for consumption of the general public, especially, the academic sector, were excluded from this research.

3 Results and Discussion

3.1 Delineation of Artificial Intelligence: A digital skill

In recent years, the agricultural sector is dealing with much pressure to satisfy human needs for food at least to not less than seven (7) billion people in the world. The growth estimation that by 2050 the sector will have to feed not less than 9.7 billion people (FAO, 2017). Therefore, the introduction of Artificial Intelligence (AI) is to aid the sector to deliver to the demands of the ever-growing population across nations of the world. AI refers to a field in computer science that focuses on the development of machines to perform the same tasks usually required of Human Intelligence (Trendov *et al*., 2019 and Yadav *et al*., 2020). It is also viewed as a computerized ability to perform tasks usually performed by humankind, which then aids humankind to accomplish some tasks (timeously) effectively and efficiently (Sithole, 2020 and Sharma & Sood *et al*., 2022). AI is essential for the very reason that the agricultural sector is labour intensive, and this reduces efficiency, effectiveness, and profitability (Kaushal *et al*., 2022). Therefore, AI tools will leverage the stress faced with farmers.

It is an undisputable fact that the agricultural sector needs the superhuman ability to harness decision-making processes effectively and efficiently. Agrarians know that decision making in the sector must be precise and timely. Therefore, AI comes with such benefits, especially in the era of changing climatic conditions and rising food demands. AI is regarded to be the digital skills of essence in the sector for its support to achieving sustainable agriculture (Kaushal *et al*., 2022). The new concept of smart sustainable agriculture is key to the AI discussion and vice versa. Studies suggest a 37.3% growth rate of the agricultural sector with the aid of the AI tools between 2020 – 2050 (Sood *et al*., 2022; Bannerjee *et al*., 2018; Kaushal *et al*., 2022). Therefore, it is of the essence to discuss these digital skills for the sector, particularly, for the rendering of Agricultural Advisory Services. These digital skills are for optimal pest control, soil health and moisture contents monitoring, analysis of data for farmers, and the production of high-quality crops.

3.2. The opportunities of Artificial Intelligence for Agricultural Advisory Services

The benefits of Artificial Intelligence (AI) in the agricultural sector were highlighted in the conceptual framework of the study, section 1.1. of this paper. These benefits necessitate information dissemination among the stakeholders of the sector, especially the farmers. Farmers are divided into two major groups in the sector, namely commercial and subsistence (smallholder) farmers. On the other hand, Agricultural Advisory Services (AASs), also known as Agricultural Extension Services (AESs), are provided to agrarian farmers in two forms, namely public and private Extension Services. Therefore, it is of the essence to delve into the opportunities of AI in the delivery of Agricultural Advisory Services. These are:

i. Automation and data analysis

Artificial Intelligence (AI) has a critical role to play in the automation of Agricultural Advisory Services (AASs), which will fundamentally change how farmers receive advice and assistance. AI facilitates the creation of advanced technologies like Chatbots and Machine Learning algorithms that automate and expedite the distribution of vital information to farmers (Grover *et al*., 2022). By acting as Virtual Agricultural Advisers (VAAs), chatbots improve accessibility to advisory services by responding to inquiries in real-time and giving tailored advice. In contrast, machine learning algorithms examine large agricultural data to spot trends, anticipate crop diseases, enhance planting schedules, and provide market insights (Bharadiya, 2023). Farmers may make better decisions with the help of this data-driven strategy, which also enables pre-emptive steps to reduce risks and increase yields. Furthermore, AI-powered instruments such as Predictive Analysis support early warning systems for possible agricultural risks, enabling farmers to take preventative measures (Zhang *et al*., 2021). In addition to the Chatbots, and Machine Learning Algorithms (MLAs), there are tools like the Mobile Computing (MC), Remote Sensors (also known as Drones), and Robotics and Autonomous Systems (RAS) and the Farm Radio (which is also an international tool that can be used at an international level) which the VAAs can use.

However, the use of the latter AI tools requires the active participation of the farmers in the field, except for the Farm Radio. The Farm Radio functions in a manner that is can potentially support over 700 radio shows across the world. Moreover, it is a system where one (1) Agricultural Advisor reach out to at least 4000 farmers at one in the world (Sanga *et al*., 2013; Rao, 2015; Mhlaba & Yusuf, 2020 and Talaviya *et al*., 2020). On the other hand, the drone is used by the farmers to collect real-time useful data on the farm and share it with the readily available Virtual Agricultural Advisor for possible advice. This is an indication that the future is bright for the sector.

ii. Efficiency

By revolutionising the methods of processing, analysing, and translating data into insights that farmers can use, artificial intelligence (AI) greatly improves the efficiency of agricultural extension services. AI technologies can handle huge and diverse datasets with amazing speed and precision (Kaushal *et al*., 2022 and Grover *et al*., 2022). Examples of these technologies are Machine Learning Algorithms (MLAs) and Data Analytic Tools (Such includes Crop and Animal Health Indicators, Soil Moisture Content Sensor, and Pests Indicator/Monitor). Agricultural extension services may expedite the examination of variables such as soil composition, weather patterns, past crop performance, and market trends by using these innovations (Bhat and Huang, 2021 and Bharadiya, 2023). Farmers can, therefore, allocate resources more efficiently, implement best practises, and predict problems ahead of time. AI also makes predictive modelling easier, enabling extension agencies to anticipate agricultural yields, spot disease outbreaks, and suggest the best times to begin sowing. Furthermore, based on unique farm circumstances, AI-driven technologies can customise Agricultural Advisory Services and offer recommendations that are tailored to meet demands (Messina *et al*., 2020). Thus, this degree of personalization increases farmers' confidence and involvement while also making the recommendations more relevant.

iii. Revolutionising industries

Artificial intelligence (AI) has the potential to completely alter the Agricultural Advisory Services by providing groundbreaking solutions that can push the industry's productivity, sustainability, and efficiency to all-time highs (Shah and Aggarwal, 2023). Unprecedented insights are made possible by AI's ability to analyze enormous volumes of agricultural data, including crop performance, weather patterns, soil health, and market trends (Javaid *et al*., 2023). By identifying complex patterns in this data, machine learning algorithms enable agricultural extension services to provide farmers with more tailored and precise advice. Hence, AI incorporated tools make it easier to monitor farm conditions in real-time, which supports prompt interventions and resource optimisation (Patil *et al*., 2023). Additionally, AI frees up human resources in the agricultural extension sector to concentrate on research, community involvement, and strategy planning by automating repetitive jobs and data analysis. AI integration has the potential to increase access to cutting-edge agricultural information, helping all sizes of farms and promoting sustainability in the process (Bhat and Huang, 2021). Essentially, AI's transformation in the delivery of Agricultural Advisory Services provides the potential for building a more inclusive, data-driven, and resilient global agriculture in the future.

iv. Personalised experiences

By examining distinct farm data, such as crop success in the past, weather patterns, soil quality, and socioeconomic aspects, AI can customize advice and suggestions to meet the unique requirements of every farmer (Shaikh *et al*., 2022). By identifying patterns and connections that conventional approaches can miss, machine learning algorithms facilitate the creation of more precise forecasts and insights (Mekonnen *et al*., 2019). By providing farmers with useful information, this tailored approach not only makes advice more relevant but also maximizes resource allocation and decision-making. Artificial intelligence-driven technologies can adjust to the changing conditions of agricultural operations, providing prompt resolutions to problems like insect infestations or unpredictable weather patterns (Toscano-Miranda *et al*., 2022). Additionally, AI promotes a higher degree of connection and trust between farmers and agricultural extension services by automating routine activities and delivering timely, customized information.

3.3. The challenges of Artificial Intelligence in Agricultural Advisory Services

In as much as AI comes with numerous benefits and opportunities for the agricultural sector, especially to Agricultural Advisory Services (AASs). However, there are several challenges that affect the AASs, especially in the implementation of Artificial Intelligence technologies to agricultural activities. The challenges include lack of digital infrastructure and connectivity in rural areas, limited access to technology and digital skills among farmers, limited access to funding for digital initiatives in agriculture, data privacy and security concerns, inadequate regulatory framework, and resistant to change (Mhlanga and Ndhlovu, 2023). De Oliveira and de Souza e-Siliva conducted a study in 2023, with a quest to identify the benefits, challenges, and trends of Artificial Intelligence in the Agricultural Sector. Their study found that the challenges of AI in the sector include the risks associated with small and medium farms, mapping and digitalization, labour qualification, data ownership, and sustainable integration of big data sources. Another study by Cosmin (2011) which focused on the adoption of artificial intelligence in agriculture revealed that the first obstacle to utilizing the new technology is undoubtedly the underdeveloped IT infrastructure in many countries, with only 30.2% of the global population having access to the internet. Language difficulties and lack of computer expertise are other significant reasons why computers are not used widely. Certain expert systems are restricted to usage by a limited number of farmers since they are intended to cover a particular agricultural region. According to Bohara (2008) on a study about strategic implementation of ICTs in agriculture information dissemination: a case of Gulmi districts, found that technical challenges have a massive impact on the use of ICTs in agriculture. This technology needs robust infrastructure, and in rural areas there are poor road infrastructure that hinders farmers to move from one place to the other to get exposure about technologies that is not accessible in their communities, including good network connectivity (Musa *et al*., 2012).

AI systems need large amounts of data to train their computers and make accurate forecasts and predications. While obtaining time data can be difficult, spatial data can be gathered with ease in the event of a very large agricultural area (Linsner *et al*., 2021). Building solid AI machine learning model requires a significant amount of time, as the database takes time to mature (Kaur *et al*., 2018). This is one of the main reasons AI is used in agronomic products rather than on field precision solutions such as seeds, fertilizer, and insecticides. Agricultural technology providers (ATPs) are producing conflicting legal data usage agreements as a result of the absence of standardized data protection policies in farming (Guntamukkala *et al*., 2015). Farmers were consequently left with little or no control over their data. Additionally, Kaur *et al*., (2022) argues that protecting farmers' data, privacy and confidentiality is of paramount importance. It is therefore strongly recommended that considerations be made to ensure that outside parties do not receive farm data without farmers' permission. This is since transparency about the gathering, using, sharing, and disclosing of farmer data is crucial for work ethics, particularly, in AASs. However, in areas where there is lack of trust and openness between AAs and farmers, information sharing becomes very difficult, and this impedes the achieving the development goals.

One of the main issues is lack of proficiency with which small-scale farmers use digital technology infrastructure in rural areas (Munyua, 2007). Musa *et al*., (2013) argues that the adoption and use of ICT by small-scale farmers in Gezira State, Sudan, has been hindered by the lack of energy infrastructure and researchers' inadequate proficiency with digital technology. This further prevents farmers from receiving agricultural information. Poor educational attainment, low income, cultural inertia, and a death of locally relevant information available in local languages among others, contributes to the lack of acceptance of relevant and important technologies in the sector (Musa *et al*., 2013). Similarly, Nmadu *et al*., (2013), established that the biggest obstacle to small scale farmers in Nigeria in using digital technology to obtain commercial information are the farmers' level of educational attainment, poverty, and language. According to Odini (2014), the access to and use of agricultural information by small scale women farmers in support of efforts to attain food security in Vihiga County, Kenya, remains very low. This is assumed to be because of small-scale farmers in Kenya having a lack access to appropriate information services, infrastructure, technical competences, and lower levels of educational attainment, which attributes to high levels of farmers' lack of knowledge. Similar findings were presented by Smidt and Jokonya, (2022) when evaluating the factors influencing the adoption of digital technology and tools among smallholder farmers in South Africa. Gillespie *et al*., (2007) and Paudel *et al*., (2011) argue that while technology advances, farmers' attitude towards using new innovations also evolves with time. Furthermore, due to high costs, time constraints, and satisfaction with current practices, farmers in the United States of America did not implement profitable farming technology (Paudel *et al*., 2011). Therefore, most of the issues raised in literature evolves around the low adoption of digital agricultural tools for improved efficiency and effectiveness. However, there are some other challenges which authors believe can also impact the delivery of extension services across the world. These include the ethical issues such as privacy, confidentiality, fairness, accountability, accuracy, and reliability of the dataset (Ngo *et al*., 2019 and Grover *et al*., 2022).

4 Conclusion and Recommendation

In the world of fast technological innovation and advancement, digital skills are crucial to keep the agricultural sector on track and in business. The sector is faced with multiple challenges simultaneously, such incudes the ever-changing climatic conditions, the increase in the number of people across the globe, the increasing demands for food, fiber, and energy, just to name a few. Therefore, it is an undisputable fact that the sector is called to act swiftly to ensure the preservation of the human species. That is in terms of advancing in digital skills and adoption of Artificial Intelligence (AI) to aid the currently over-burned technologies and use of human intelligence and animal energy to get work done in the sector. AI will aid the sector in many ways including in rendering Agricultural Advisory Services (AASs), improving both real-time data collection, analysis, and interpretation for proper recommendations. These will be achieved through the use the digital skills and tools readily available for both the farmers and Agricultural Advisors (AAs). The AI tools readily available for use by farmers, both the commercial and smallholder farmers include remote sensors (Drones), intelligent spraying machines, automated milking machine, unmanned aerial machines and agricultural robots.

These AI tools will aid the sector to meet the growing needs of the general public by improving on the time taken to produce, package and resources management, responsibility shifts which reduces the costs of production, particularly on labor costs. There are still challenges that come with the implementation of AI and digital skills in the sector. These include the reliability of the datasets, ethical issues, quality of the datasets and the shortages of personnel with the appropriate skills needed to operate these AI tools and equipment, even remotely. More research projects are underway seeking to uncover the acceptability of AI by the general public, making use of the agricultural output produced through the use of AI tools, the willingness of farmers to invest in the AI tools, equipment and infrastructure, the preparedness of AASs in the use of AI to enhance the rendering of services to the Extension Clients. In as much as this is ongoing, the involvement of young people in the agricultural sector is projected to rise with the number of skilled young people who are unemployed. Therefore, it is recommended that studies unveiling the support needed for smallholder farmers in rural areas be conducted, especially in developing countries where AI and Digital Technology infrastructure is not readily available. The relationship between youth participation in the agricultural sector and the implementation of AI and Digital Technology in the sector must also be explored, with the impact of the implementation of AI in the sector and the contribution of the sector towards developing countries' Gross Domestic Products (GDPs). The ethical implications of AI in AASs and the Agricultural Sector as a whole must be explored to unveil issues that may hamper the future acceptance of these digital skills and innovations.

5. Acknowledgements

The authors would like to acknowledge the University of Mpumalanga for funding their conference attendance.

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