



JOURNAL OF SCIENCE, TECHNOLOGY AND EDUCATION (JSTE)



**A PUBLICATION OF THE
DEPARTMENT OF SCIENCE,
TECHNOLOGY AND MATHEMATICS
EDUCATION (STME),
NASARAWA STATE UNIVERSITY, KEFFI, NIGERIA**



VOLUME 10

ISSN: 2651-5539

AUTOMATED AGRICULTURAL PRACTICES IN AFRICAN TERTIARY INSTITUTIONS AND RESEARCH INSTITUTES: A REVIEW

¹Edegbe, G. N., and ²Adade, B. F.

¹Department of Computer Science, Edo State University, Iyamho, Nigeria.

²Principal, Junior Secondary, Word of Faith Group of Schools, G.R.A., Benin City, Nigeria.

Corresponding author: edegbe.glory@edouniversity.edu.ng

Citation: Edegbe, G. N., & Adade, B. F. (2026). Automated agricultural practices in African tertiary institutions and research institutes: a review. *Journal of Science, Technology, and Education (JSTE)*; www.nsukjste.com/. 10(40), 563–578.

Abstract:

Automated agricultural practices are part of the solution to challenges in rural Africa, including the poor attitude of youths toward enrolling in agricultural courses at tertiary institutions, the unwillingness of graduates to practise farming, and climate change. Such practices include precision agriculture, automated farming systems (automated irrigation, automated fertilisation, automated crop monitoring, livestock automation, as well as data-driven decision-making facilitated by technology). This review assesses the current agricultural practices and education in tertiary institutions, how automation technologies can improve farming practices and education in tertiary institutions, the benefits and challenges of implementing automated agricultural practices, and how the identified challenges can be addressed by examining related literature and reports from 2010 to 2025

sourced from databases such as Google Scholar and Scopus. The findings indicate that precision agriculture technologies, automated irrigation systems, livestock monitoring technologies, crop management technologies, farm management information systems, and robotics and mechanization have been adopted by several African tertiary institutions and research institutes. The review further reveals that automation in African agriculture is already producing positive impacts amid several challenges. The study recommended that several challenges related to the adoption of automated agriculture be addressed by African governments and regional and international development agencies through policy interventions, funding, and capacity building to effectively leverage the benefits of automated agricultural practices.

Keywords: Automation; Agricultural practices; Tertiary institutions; Adoption Challenges; Review; Africa

Introduction

African agriculture has been characterized by traditional methods of production and processing, using local, crude implements. These methods are labour-intensive, and farmers can hardly grow crops and rear

animals on a large scale. As a result, productivity is low, leading to low income and entrenched poverty spanning several generations among the majority of the smallholder farmers (Muzira & Bondai, 2020; RUFORUM, 2017). All these make

farming unattractive to the youth, especially the educated ones.

Therefore, African agriculture needs to be modernised to motivate young adults to pursue innovative, profitable enterprises. Already, some African countries have kick-started the deployment of automated technologies in agriculture. For instance, the Zimbabwean government has implemented reforms in tertiary education, shifting the focus from research, teaching, and community service to five areas (research, teaching, community service, innovation, and industrialisation) (Muzira & Bondai, 2020). This approach is likely to be activated through automated agricultural practices.

Automated agricultural practices refer to the use of technology, machinery, and equipment to operate using machines/computers instead of people to carry out various aspects of agricultural production, processing and management (Aggarwal et al., 2024). This can take the form of precision agriculture, involving the use of GPS and GNSS, drone technology, and satellite imaging (Mathur, 2023). It may also come as automated farming systems that include automated irrigation, fertilisation, and crop monitoring. Moreover, automated agricultural practices have also been considered to include livestock automation involving automated feeding, automated livestock health monitoring and automated milking. In

broader terms, data-driven decision-making, facilitated by technology, is also part of automated agricultural practices. This may include data analytics and artificial intelligence deployed in farm management. These practices described above are likely to help farmers and agricultural businesses increase efficiency, reduce costs, and improve productivity while also promoting sustainability. Although not specific to Africa, studies by Paramathma et al. (2023), Younas et al. (2020), and Zhang et al. (2023) demonstrated the relevance of smart precision agricultural systems that use machine learning algorithms. These systems integrate real-time field information, soil quality data, and weather parameters to optimize crop selection and management. The adoption of such technologies in Africa could significantly enhance agricultural decision-making, increase productivity, and improve resource management.

Current agricultural practices in African tertiary institutions are evolving in ways to mitigate the challenges faced by African agricultural systems. Such challenges, according to RUFORUM (2017) and Chirinda et al. (2024), include the unsatisfactory performance of agricultural education systems in Africa based on indicators like high unemployment rates of agricultural graduates, agricultural product value chains' inefficiencies as well as a decline in enrolment in schools of agriculture

and faculties of agriculture in the universities. The university's role in contributing to knowledge-based economies and decision-making in the agricultural sector has attracted renewed interest in Africa (AI-Youbi et al., 2021). According to Chirinda et al. (2024), some of the practices being implemented in African tertiary institutions include: Agri-entrepreneurship education, practice-based entrepreneurship courses, the creation of incubation centres, collaboration with industry partners, and community engagement. Universities have contributed to research, education, training, capacity building, and knowledge transfer (RUFORUM, 2017). Therefore, tertiary institutions can be veritable tools for promoting the much-needed agricultural revolution and development in Africa.

However, African universities often operate on theoretical grounds and adopt Western ideologies, values, governance systems, and research outputs, which are sometimes misapplied in addressing local societal needs and practices (Bjornlund et al., 2020). Also, a study by Farayibi and Folarin (2021) demonstrated that African governments' spending on tertiary institutions is less compared to that of lower levels – primary and secondary education, while less than 1.0% of the GDP is spent on tertiary education compared to 2.5% spent by countries in North America and Western Europe in 2018. This, in turn, affects the

quantum of investment in automated agricultural practices in tertiary institutions in Africa.

Considering the nexus between automated agricultural practices and the overall agricultural development in any nation, it is imperative to know the situation of automated agricultural practices in African tertiary institutions based on the fact that graduates exposed to such systems are likely to change the practices in the agricultural terrain in their various domains (Kafando et al., 2022). Besides, the existing literature, including Dengila et al. (2023) on the state of automated agricultural practices in Africa, did not extend to research institutes; their work was limited to tertiary institutions. The situation in both African tertiary institutions and research institutes has not been considered. This research gap needs to be bridged.

It is against this background that this study sought to review the documented automated agricultural practices in both African tertiary institutions and research institutes. In doing the review, the following research questions were asked:

1. What are the current automated agricultural practices in African tertiary institutions and research institutes?
2. What are the adoption patterns of such technologies?
3. How can automation technologies improve agricultural practices and

education in African tertiary institutions and research institutes?

4. What is the framework for the implementation of automated agricultural practices in African tertiary institutions and research institutes?
5. What are the challenges of implementing automated agricultural practices in African tertiary institutions and research institutes, and how could these challenges be addressed?

By exploring the potential of automated agricultural practices in tertiary institutions, this research can improve the quality and relevance of agricultural education, enhance efficiency and productivity, and advance research and development in agriculture not only in African tertiary institutions but also across the broader African agricultural landscape.

Methodology

The researchers conducted a review of existing literature on automated agricultural practices, precision agriculture, and agricultural robotics. They employed a systematic approach, as adopted by Edegbe & Adade (2018) and Yakubu et al. (2024). The approach involved a rigorous search across academic databases, particularly Google Scholar and Scopus, as well as relevant

university and research institute websites, journals, conference proceedings, and online platforms to gather literature on the adoption of automated agricultural practices in African tertiary institutions and research institutes. The search encompassed literature published between 2010 and 2025 to ensure a comprehensive review of recent developments and foundational studies. The inclusion criteria focused on key concepts, including automation, agricultural practices, tertiary institutions, agricultural research institutes, adoption, and challenges.

Findings and Discussions

African agricultural practices face significant challenges, necessitating the adoption of automation in tertiary institutions. The continent's agricultural sector is mainly populated by smallholder farmers who lack access to innovative farming practices and technologies. Some key challenges are highlighted in studies (Sithole & Olorunfemi, 2024; Chirinda et al., 2024; Fiocco et al., 2023). They include: 1. Low Agricultural Productivity: Improvements in land, labour, and capital productivity are slower than in other regions, especially developed ones. 2. Climate Change and Variability: Elevated temperatures, unstable rain-dependent agriculture, and unsustainable farming practices contribute to decelerated agricultural productivity growth. 3. Food Insecurity: The region struggles with food

insecurity, exacerbated by a growing population and limited use of modern technologies. 4. Limited Access to Capital and Knowledge: Small-scale farmers battle with constraints while accessing finance, knowledge, and training, thereby hindering their ability to adopt sustainable agricultural practices. To address these challenges, automated agricultural practices can play a crucial role (Eli-Chukwu, 2019; Shehu et al., 2011; Choruma, 2024).

Current situation of automated agricultural practices in tertiary institutions and research institutes

Automation is still in its infancy in African universities (Bland, 2023). This reflects the global state of adoption of automated agricultural practices. According to McKinsey's (2022) Farmers Global Insights Survey, cited in Bland's (2023) work on trends driving automation on the farm, fewer than 5 per cent of farmers globally have adopted automated agricultural practices, while 21% are using management software.

On the basis of the kind of organisations at the forefront of AI applications to agriculture in Sub-Saharan Africa, academia is the least involved. According to the International Centre of Expertise in Montreal on Artificial Intelligence (CEIMIA) (2024), private companies lead in the development of AI solutions applied to agriculture (88.2%). Civil Society Organisations come next

(8.8%), followed by academia (2.9%). Agriculture also ranks low in the deployment of digital technologies in Africa.

The review of some literature, Onyango et al. (2021), Dengila et al. (2023), FAO (2017), AATF (2020), WAAPP (2020), Adeyemi (2017), and IFPRI (2020), indicated that automation in agricultural practices is gaining traction in African universities and research institutes. For instance, West African universities are increasingly adopting automated agricultural practices to enhance food security, sustainability, and student employability. Notable initiatives are:

1. The University of Ibadan's Department of Agricultural Engineering, as well as the University of Abomey-Calavi 's Faculty of Agricultural Sciences, have developed automated agricultural technologies like robotics and mechatronics, and have also deployed them for use in experimental farms.
2. The Kwame Nkrumah University of Science and Technology's College of Agriculture and Natural Resources has implemented automated systems for crop management and livestock monitoring.

Notable automated practices are found to be adopted in both universities and research institutes in Africa. They include precision

agriculture with techniques such as crop monitoring via drones, sensor-based soil analysis and satellite imaging (IFPRI, 2020); mechanised irrigation systems integrated with sensors and weather data to optimise water use, thereby reducing waste (Edegbe & Adade, 2018); robotics and mechatronics integrated with mechanisms that ensure crop management, livestock monitoring, and farm equipment maintenance. There is also data-driven farming, which uses data analytics and machine learning to implement cost-effective farming practices and predict crop yields.

It was also observed from the review that West African research institutes have continued to adopt automated agricultural practices in an increasing manner to promote food security and innovation. Examples of research institutes identified as carrying out such practices include the International Institute of Tropical Agriculture (IITA), which has implemented precision agriculture techniques like drones and satellite imaging to improve crop yields and reduce waste, and the West Africa Agricultural Programme, which has adopted practices like robotics and mechatronics to enhance productivity and competitiveness. Other institutes include the National Agricultural Research Institute (NARI), which has also implemented automated systems for crop monitoring and irrigation management to improve crop yields and reduce waste, as well as the Council for

Scientific and Industrial Research (CSIR), adopting automated agricultural practices such as precision agriculture and data-driven farming to enhance agricultural innovation and productivity.

Patterns of automated agricultural practices adoption in African universities/research institutes

According to Lee et al. (2019) and the Higher Education Academy (HEA) (2019), adoption patterns in universities and research institutions are influenced by various factors that shape the integration of new technologies and innovations. Notable factors considered include: (a) The ease of using an innovation based on the performance expectancy theory, (b) The ease of adopting an innovation based on the effort expectancy theory; (c) Peer impact on the adoption decision due to social influence from the environment; (d) Availability of support and resources which tend to facilitate innovation adoption; and (e) The readiness to adopt and use an innovation based on the individual behaviour and conviction.

Research findings from studies by Kim and Malhotra (2005), Hariri and Roberts (2015), OECD (2020), HEA (2019) and Gwagwa et al. (2021) have thrown weight behind other factors influencing the adoption of agricultural technologies. These include demonstrability, visibility, trial-ability, and reinvention. The studies also showed that the

Unified Theory of Acceptance and Use of Technology (UTAUT) model has been widely used to explain adoption behaviour in West African tertiary institutions and research institutes.

Figure 1 presents our proposed conceptual framework, derived from a synthesis of the reviewed literature, for implementing automated agricultural practices in African tertiary institutions and research institutes. It is made up of six stages: Enabling Environment, Capacity building, Technology

adoption, Implementation, Monitoring and Evaluation, and Outcomes. The enabling environment provides the foundation for capacity building. Why capacity building facilitates the adoption of automated technologies. When these automated technologies are implemented, monitored, and evaluated, this will lead to enhanced agricultural education, research output, and sustained agricultural development, as shown in the outcomes stage.

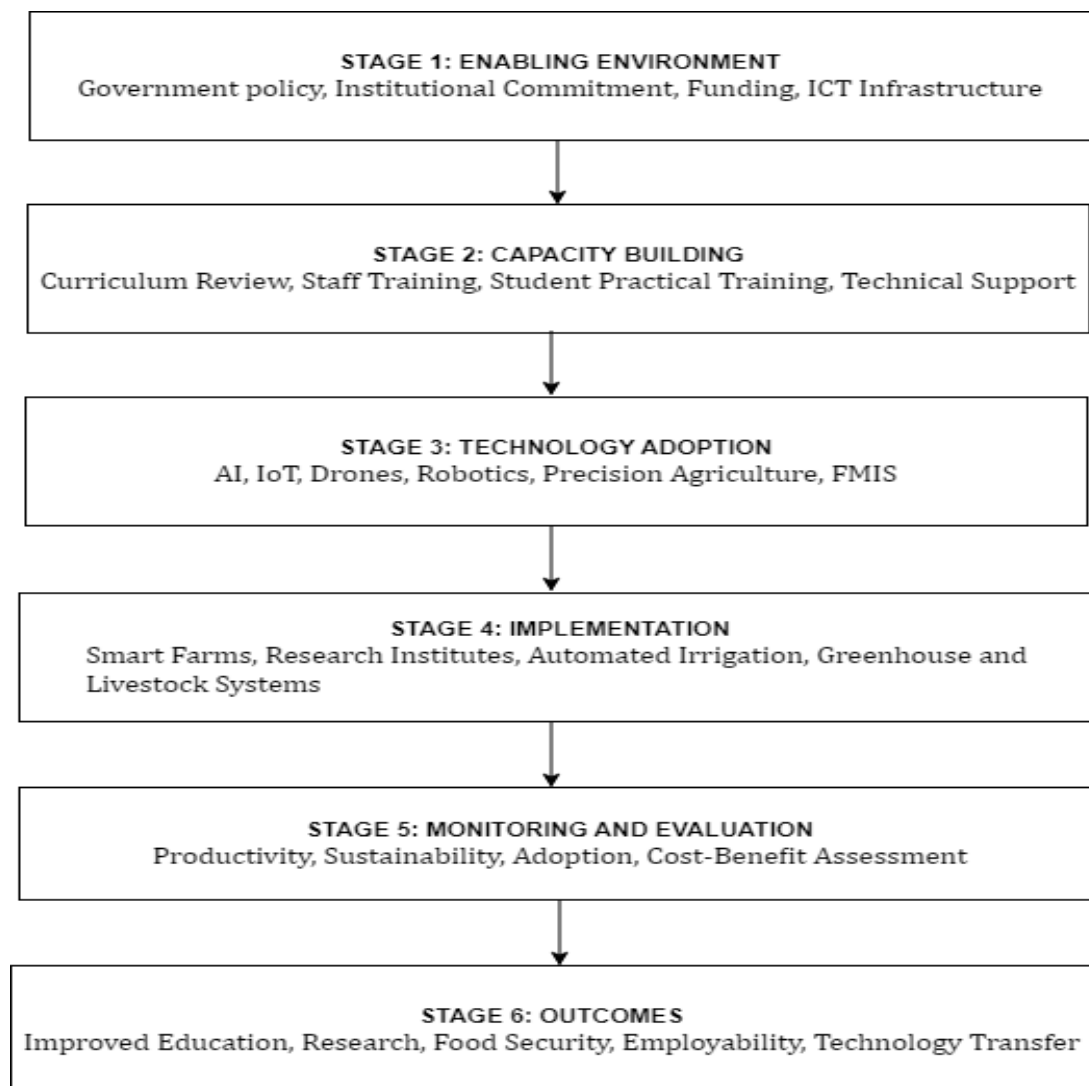


Figure 1: Proposed Conceptual Framework for the Implementation of Automated Agricultural Practices.

Adoption of automated agricultural practices and challenges faced by African tertiary institutions

African tertiary institutions face several challenges as they embrace automated agricultural practices. Pertinent challenges identified by some researchers, Gwagwa et al., (2021), Gikunda (2024), Marina et al. (2025), Sithole and Olorunfemi (2024) and RUFORUM (2017), are discussed below:

There is the challenge of resource management. This presents itself in terms of insufficient funding for infrastructure, equipment, and personnel, thereby hindering the adoption of automation technologies. It may also manifest as outdated or inadequate infrastructure, such as internet connectivity and power supply, which can limit the effectiveness of automation technologies. Human resource constraints may exist in the form of shortages of skilled personnel and inadequate training programs, which can hinder the implementation and maintenance of automation technologies. Furthermore, poor equipment maintenance stems from limited access to spare parts, maintenance services, and technical support, leading to equipment downtime and reduced productivity.

Secondly, there is a sustainability challenge in the form of inadequate energy consumption. This is common in areas with limited or unreliable energy supply. The use of automation technologies can also present

environmental implications, such as e-waste generation and resource depletion.

Thirdly, dependence on external funding is often not sustainable. Institutions relying on external funding have found such sources unpredictable and unsustainable in the long term.

Furthermore, the African environment has limited local capacity for manufacturing, maintenance, and repair of automation technologies, thereby causing dependence on external expertise.

The identified challenges could be tackled in a number of ways. These may include: Partnerships and collaborations with industry partners, governments, and international organizations to access funding, expertise, and resources, as well as capacity building: involving investment in training programs, workshops, and conferences to build local capacity and expertise in automation technologies. Other ways include adopting sustainable practices, such as energy-efficient solutions and e-waste recycling, to minimise environmental impact, and exploring innovative funding models, such as public-private partnerships, to reduce dependence on external funding (CEIMIA, 2024; Sithole & Olorunfemi, 2024).

Methods of improving automated agricultural practices and education in the African agricultural landscape

Tertiary institutions in Africa can improve the adoption of automated agricultural

practices in a number of ways. These may include provision of training and education involving the offering of courses and training programs on precision agriculture, automation, and sustainable farming practice; Conduct of research and development entailing collaborating with industry partners to develop and adapt automated technologies for African farming contexts; Promotion of policy and regulatory frameworks that involves advocacy, policies and regulations that support the adoption of automated agricultural practices.

African tertiary institutions can help address the continent's agricultural challenges and promote sustainable food systems by embracing automated agricultural practices (Sithole & Olorunfemi, 2024; Yakubu et al., 2024; CEIMIA, 2024). Data from some empirical studies support the adoption of automated agricultural technologies in African tertiary institutions. Some primary and intriguing findings from such studies are discussed below: A study by the African Agricultural Technology Foundation (AATF) (2020) highlights the impact of automated agricultural technologies on smallholder farmers, including increased yields and improved livelihoods. Another research by the University of Nairobi's Department of Agricultural Economics, Extension and Rural Development explores the adoption of precision agriculture technologies in Kenya, citing benefits such as

enhanced crop management and reduced waste. Furthermore, a paper by the International Food Policy Research Institute (IFPRI) (2020) examines the role of automation in African agriculture, emphasizing its potential to boost productivity and food security.

Other institutional examples include: The collaboration between the University of Kigali and the AATF on initiatives like the Rwanda Agriculture Board (RAB) which helped to promote agricultural innovation and technology adoption; the Federal University of Agriculture, Abeokuta's specialised programmes in agricultural engineering and agribusiness, with emphasis on research in automation and precision agriculture; as well as the University of Dar es Salaam's partnership with organizations like the African Seed Trade Association to advance agricultural development and technology transfer in Tanzania.

The key technologies employed include: Precision agriculture utilizing technologies like drones, satellite imaging, and sensors for optimized crop management; Automated irrigation systems enhancing water efficiency and crop yields through advanced irrigation management; and Livestock monitoring technologies which employ RFID tags, sensors, and automated feeding systems to improve animal health and productivity (FAO, 2017; FAO, 2020).

How automation technologies, such as precision agriculture, automated greenhouse management, and agricultural robotics, can improve agricultural practices and education in African tertiary institutions

Automation technologies can significantly improve agricultural practices and education in African tertiary institutions (Patel, 2023; Gikunda, 2024). Some of the approaches are discussed below:

Improved automated agricultural practices can optimize resource utilization, reducing costs and enhancing productivity. This enhances farm efficiency. Precision agriculture and automated systems provide valuable data, enabling farmers to make informed, data-driven decisions. Automation promotes sustainable farming practices, minimizing environmental impact and ensuring food security. Furthermore, precision agriculture and automated systems can help farmers improve crop yields and reduce waste.

Enhanced education and training on automation technologies provide students with hands-on experience, preparing them for the modern agricultural industry. This improves practical farm experience. Moreover, automation technologies provide students with research opportunities, thereby enabling them to explore innovative solutions for African agricultural challenges. Specifically, precision agriculture promotes the development and utilization of technologies like drones, sensors, and AI

which enhances real-time crop monitoring and data-driven decision-making. In addition, Automated Greenhouse Management enhances climate control, irrigation, and fertilization, thus improving crop yields and reducing waste. In the same vein, Agricultural Robotics enhances efficiency and productivity in tasks like planting, harvesting, and crop monitoring.

Automation technologies can automate data collection, reducing the need for manual data entry and minimising errors, thereby increasing efficiency and productivity. Automation technologies can optimize farm operations, such as planting, irrigation, and harvesting, reducing labour costs and improving productivity. Automation technologies can improve crop yields by providing optimal growing conditions, detecting pests and diseases early, and optimizing fertilizer and water usage.

Automation technologies can provide real-time data analytics, enabling farmers and researchers to make informed decisions about farm operations, crop management, and livestock health. Automation technologies can utilize predictive modelling to forecast weather patterns, crop yields, and livestock health, enabling proactive decision-making. Automation technologies can help manage risks associated with farming, such as weather-related risks, pests, and diseases.

Automation technologies can provide digital platforms for collaboration and knowledge sharing among farmers, researchers, and students. This will facilitate data sharing, enabling researchers and farmers to access and share data, best practices, and research findings. Extension services can also be enhanced by providing farmers with access to expert advice, training, and support (Abbasi et al., 2022).

The benefits of these technologies for African Tertiary Institutions, as observed by some authors, Kudama et al. (2021), Kolawole et al. (2023) and Choruma et al. (2024), may include: 1. Improved Employability: Graduates with experience in automation technologies are more attractive to employers. 2. Increased Research Funding: Automation technologies can attract research funding, enabling institutions to explore innovative solutions. 3. Enhanced Reputation: Institutions that adopt automation technologies can enhance their reputation and attract top talent. 4. Contribution to Sustainable Development: Automation technologies can contribute to sustainable development, aligning with the United Nations' Sustainable Development Goals (SDGs).

By embracing automation technologies, African tertiary institutions can improve agricultural practices, enhance education, training, and research, and contribute to

sustainable development. Moreover, by leveraging automation technologies, tertiary institutions can increase efficiency and productivity, and promote better decision-making, collaboration, and knowledge sharing.

Lessons for tertiary institutions in sub-Saharan Africa regarding the success of automated agricultural practices in tertiary institutions in Africa and other continents

Tertiary institutions in Sub-Saharan Africa can learn valuable lessons from the success of automated agricultural practices in tertiary institutions across Africa and other continents. Here are some key takeaways from studies (Chirinda et al., 2024; World Bank, 2020; Mrema, 2017).

Lessons from Africa:

1. Collaborate with industry partners, research institutions, and government agencies to access funding, expertise, and resources.
2. Adapt automated agricultural practices to local contexts, taking into account climate, soil, and cultural factors.
3. Provide training and capacity-building programs for staff, students, and farmers to develop technical expertise.
4. Integrate automated agricultural practices into existing curricula to

enhance student learning and research.

5. Foster entrepreneurship and innovation by encouraging students to develop business plans and prototypes for automated agricultural practices (Thompson, 2024).

Lessons from other Continents:

Some notable examples of successful agricultural automation initiatives in other continents include Japan's precision agriculture, India's, and the Netherlands' digital agriculture (Kumar & Singh, 2020; FAO, 2017). The lessons from those initiatives, which can provide valuable insights for sub-Saharan Africa as it seeks to develop its agricultural automation sector, are discussed below:

1. Invest in modern infrastructure and equipment to support automated agricultural practices.
2. Utilize data analytics and precision agriculture techniques to inform decision-making and optimize agricultural practices.
3. Prioritize sustainability and environmental impact by implementing automated agricultural practices that reduce waste, conserve water, and promote eco-friendly farming methods.

4. Develop specialized programs and courses in automated agriculture to address the growing demand for skilled professionals.

5. Foster interdisciplinary collaboration among faculty, students, and industry partners to drive innovation and solve complex problems in automated agriculture.

From the foregoing, it is generally advisable for African tertiary institutions wishing to automate their agricultural practices to impact the wider society positively to do the following:

1. Begin with pilot projects and scale up gradually to ensure sustainability and impact.
2. Foster a culture of innovation by encouraging experimentation, creativity, and risk-taking to drive innovation and entrepreneurship.
3. Develop strategic partnerships by collaborating with industry partners, research institutions, and government agencies to access resources, expertise, and funding.
4. Invest in human capital by providing training and capacity-building programs for staff, students, and farmers to develop technical expertise.
5. Regularly monitor and evaluate progress to identify areas for

improvement and ensure that automated agricultural practices are meeting their intended objectives (Mwangi et al., 2020).

Conclusion

When automated agricultural practices are adopted and implemented as intended in tertiary institutions, the outcomes can be significant. The outcomes may include improvements in agricultural education; enhanced efficiency and productivity of agricultural operations in tertiary institutions; and facilitation of research and development in agriculture, particularly in areas such as precision agriculture and agricultural robotics. However, there could be some potential challenges, such as infrastructure and resource constraints, while supporting the implementation of automated agricultural practices; extensive work is required in integrating automated agricultural practices into existing curricula that may demand significant changes and updates, as well as training and capacity building of educators, researchers, and students to effectively use and maintain automated agricultural systems. These challenges should be addressed by African governments and by regional and international development agencies through policy interventions, adequate funding, and capacity building to properly leverage the benefits of automated agricultural practices.

References

- Abbasi, R., Martinez, P., & Ahmad, R. (2022). The digitisation of agricultural industry: A systematic literature review on Agriculture 4.0. *Smart Agricultural Technology*, 2, 100042. <https://doi.org/10.1016/j.atech.2022.100042>
- Adeyemi, O., Grove, I., Peets, S., & Norton, T. (2017). Advanced monitoring and management systems for improving sustainability in precision irrigation. *Sustainability*, 9(3), 353.
- African Agricultural Technology Foundation. (2020). *Agricultural technology adoption in West Africa: A guide for policymakers*.
- Aggarwal, S., Bansal, S., & Goel, R. (2024). AI in agriculture: A looming challenge, a gleaming opportunity. *International Journal of Engineering Science and Humanities*, 1(1), 43–52. <https://www.ijesh.com/j/article/view/s/358>
- AI-Youbi, A. O., Zahed, A. H. M., Nahas, M. N., & Hegazy, A. A. (2021). The roles of universities in development. In *The leading world's most innovative universities* (pp. 1–8).
- Bjornlund, V., Bjornlund, H., & Van Rooyen, A. F. (2020). Why agricultural production in Sub-Saharan Africa remains low compared to the rest of the world: A historical perspective. *International Journal of Water Resources Development*, 36, S20–S53. <https://doi.org/10.1080/07900627.2020.1739512>
- Bland, R., Ganesan, V., Hong, E., & Kalanik, J. (2023). *Trends driving automation on the farm*. McKinsey & Company. <https://www.mckinsey.com>
- Chirinda, N., Abdulkader, B., Hjortsø, C. N., Aitelkadi, K., Salako, K. V., Taarji, N., Mhada, M., Lamdaghi, Z., Romanova, G., Assogbadjo, A. E., Chadare, F. J., Saidi, M., Sassi, M.,

- Mugonola, B., Gogo, E. O., Ssekandi, J., Okalany, E., Egeru, A., Mshenga, P. M., & Chfadi, T. (2024). Perspectives on the integration of agri-entrepreneurship in tertiary agricultural education in Africa: Insights from the AgriENGAGE project. *Frontiers in Sustainable Food Systems*, 8, 1348167. <https://doi.org/10.3389/fsufs.2024.1348167>
- Choruma, D. J., Dirwai, T. L., Mutengi, M. J., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., & Mabhaudhi, T. (2024). Digitalisation in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in sub-Saharan Africa. *Journal of Agriculture and Food Research*, 18, 101286. <https://www.sciencedirect.com/journal/journal-of-agriculture-and-food-research>
- Dengila, J., Tognissse, I. S., Honfoga, A., Houetohossou, S. C. A., Sodedji, F. A. K., Avakoudjo, H. G. G., Tahi, S. P. G., & Assogbadjo, A. E. (2023). A survey on digital agriculture in five West African countries. *Agriculture*, 13, 1067. <https://doi.org/10.3390/agriculture13051067>
- Edegbe, G. N., & Adade, B. F. (2018). Overview of information technology in agriculture: Experiences in Africa. *The Nigerian Journal of Business and Management Sciences*, 2(2), 97–104.
- Eli-Chukwu, N. C. (2019). Applications of artificial intelligence in agriculture: A review. *Engineering, Technology and Applied Science Research*, 9(4), 4377–4388. <https://doi.org/10.48084/etasr.2756>
- Farayibi, A. O., & Folarin, O. (2021). Does government education expenditure affect educational outcomes? New evidence from sub-Saharan African countries. *African Development Review*, 33, 516–559. <https://doi.org/10.1111/1467-8268.12588>
- Fiocco, D., Vasant, G., Lozano, M. G., & Hussain, S. (2023). *Agtech: Breaking down the farmer adoption dilemma*. McKinsey & Company.
- Food and Agriculture Organization of the United Nations. (2017). *The future of food and agriculture: Trends and challenges*.
- Food and Agriculture Organization of the United Nations. (2019). *The state of agricultural automation in West Africa*.
- Food and Agriculture Organization of the United Nations. (2020). *The state of food and agriculture 2022: Policies to ensure an inclusive agricultural automation process that works for all*. <https://www.fao.org/server/api/core/bitstreams/1c329966-521a-4277-83d7-07283273b64b/content/sofa-2022/policies-inclusive-agricultural-automation>
- Gikunda, K. (2024). Harnessing artificial intelligence for sustainable agricultural development in Africa: Opportunities, challenges, and impact. *arXiv*, abs/2401.06171.
- Gwagwa, A., Kazim, E., Shawe-Taylor, J., Siminyu, K., Kachidza, P., Hilliard, A., & Smith, M. (2021). Road map for research on responsible artificial intelligence for development (AI4D) in African countries: The case study of agriculture. *Patterns*, 2(3), 100381. <https://doi.org/10.1016/j.patter.2021.100381>
- Hariri, A., & Roberts, P. (2015). Adoption of innovation within universities: Proposing and testing an initial model. *Creative Education*, 6, 186–203.
- Higher Education Academy. (2019). *Innovation adoption in higher education: Best practices and lessons learned* [Conference presentation]. Challenges in Quality Sustenance in Higher Education, APA College, Palani.

- International Centre of Expertise in Montreal on Artificial Intelligence. (2024). State of AI in agriculture in sub-Saharan Africa. <https://doi.org/10.5281/zenodo.13144813>
- Kafando, B., Pelenguel, E., & Gnedeka, K. T. (2022). Education and agricultural technology adoption: Evidence from rural India. *International Journal of Research in Business Management and Economics*, 1(1), 53–74. <https://doi.org/10.5281/zenodo.7295515>
- Kim, S., & Malhotra, A. (2005). A longitudinal model of continued IS use: An integrative view of four mechanisms underlying post-adoption phenomena. *Management Science*, 51(5), 741–755.
- Kolawole, E., Ridwanullah, A., Ayomide, A., Funsho, K., Mercy, A., & Stephen, A. (2023). Automation in agricultural and biosystems engineering. *JERR*, 25(7), 57–65.
- Kudama, G., Dangia, M., Wana, H., & Tadese, B. (2021). Will digital solution transform sub-Saharan African agriculture? *Artificial Intelligence in Agriculture*, 5, 292–300. <https://doi.org/10.1016/j.aiia.2021.12.001>
- Kumar, S., & Singh, R. (2020). Precision agriculture in India: A review. *Journal of Agricultural Engineering*, 57(2), 287–301.
- Marina, I., Bastian, A., Indriana, K. R., Sukmawati, D., Komariah, A., Hasnah, I. N., & Mukhis. (2025). Analysing the potential of agricultural technology integration in crop monitoring systems to improve the efficiency of soya bean cultivation. *Jurnal Penelitian Pendidikan IPA*, 11(12), 1007–1015. <https://doi.org/10.29303/jppipa.v11i12.13361>
- Mathur, R. (2023). Artificial intelligence in sustainable agriculture. *International Journal for Research in Applied Science and Engineering Technology*.
- Mrema, G. C. (2017). Agricultural mechanisation and automation in Africa: Challenges and opportunities. *Journal of Agricultural Engineering*, 48(2), 151–164.
- Muzira, D. R., & Bondai, B. M. (2020). Perception of educators towards the adoption of Education 5.0: A case of a state university in Zimbabwe. *East African Journal of Education and Social Sciences*, 1, 43–53. <https://doi.org/10.46606/eajess2020v01i02.0020>
- Mwangi, E., Gathenya, J. M., & Gariy, Z. A. (2020). A framework for implementing precision agriculture in African universities. *Journal of Agricultural Engineering*, 51(3), 145–152.
- Onyango, C. M., Nyanga, J. M., Wetterlind, J., Soderstrom, M., & Piikki, K. (2021). Precision agriculture for resource use efficiency in smallholder farming systems in Sub-Saharan Africa: A systematic review. *Sustainability*, 13(3), 1158. <https://doi.org/10.3390/su13031158>
- Organisation for Economic Co-operation and Development. (2020). Innovation adoption in higher education: A review of the literature.
- Paramathma, K., Kumar, M. A., Ranjith, P., & Santhosh Reddy, C. S. (2023). Development of AI based app for precision agriculture in India. In 2023 IEEE Renewable Energy and Sustainable E-Mobility Conference (RESEM) (pp. 1–5).
- Patel, H. M. (2023). The transformative role of artificial intelligence in modern agriculture. *Review of Artificial Intelligence in Education*, 4, e14.
- Regional Universities Forum for Capacity Building in Agriculture. (2017). RUFORUM vision 2030: The African universities' agenda for agricultural higher education,

- science, technology and innovation (AHESTI)—Abridged.
<https://repository.ruforum.org/system/tfd/Ruforum>
- Shehu, B., Rekwot, P. I., Kezi, D., Bidoli, T., & Oyedokun, A. V. (2011). Challenges to farmers' participation in artificial insemination (AI) biotechnology in Nigeria: An overview. *The Journal of Agricultural Extension*, 14.
- Sithole, A., & Olorunfemi, O. D. (2024). Sustainable agricultural practices in sub-Saharan Africa: A review of adoption trends, impacts, and challenges among smallholder farmers. *Sustainability*, 16, 9766. <https://doi.org/10.3390/su16229766>
- The International Food Policy Research Institute. (2020). *Agricultural automation in Africa: A review of the current state and future directions*.
- Thompson, D. (2024). African university explores data-driven smart farming. *University World News (African edition)*.
<https://www.universityworldnews.com/post.php?story=2024085102244746>
- Tsan, M., Totapally, S., Haliu, M., & Adom, B. (2019). *The digitalization of African agriculture report 2018–2019*. CTA.
<https://www.cta.int/en/digitalization-agriculture-africa>
- West Africa Agricultural Productivity Program. (2020). *Automated agricultural practices in West Africa: A review of the current state and future directions*.
- World Bank. (2019). *Digital technologies for agriculture in Africa*.
- Yakubu, M., Yakubu, U., Yakubu, H., & Ahmed, F. M. (2024). Artificial intelligence applications in sustainable agriculture in Nigeria: A comprehensive review. *Journal of Basics and Applied Sciences Research*, 2(4), 84–94.
<https://doi.org/10.33003/jobasr-2024-v2i4-70>
- Younas, O., Khan, M. Z., & Khan, I. (2020). Artificial intelligence (AI) as sustainable solution for the agriculture sector: Findings from developing economies. *Sarhad Journal of Management Sciences*, 6(2), 439–456.
- Zhang, L., Guo, W., Lv, C., Guo, M., Yang, M., Fu, Q., & Liu, X. (2023). Advancements in artificial intelligence technology for improving animal welfare: Current applications and research progress. *Animal Research and One Health*.