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Using artificial intelligence in support of climate change adaptation Africa: potentials and risks

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Climate change poses significant threats to African countries, with increasing temperatures, erratic rainfall patterns, and extreme weather events impacting ecosystems, agriculture, water resources, and human livelihoods. Artificial intelligence (AI) may offer valuable support in climate change adaptation efforts in the field of agriculture. However, considerable constraints also need to be addressed to maximise AI's effectiveness. Against this background, this article outlines the potentials and risks of deploying AI in agriculture, as well as the need for clear regulatory frameworks for AI deployment, establishing guidelines that promote innovation while addressing ethical and legal concerns.

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Introduction: the potential use of artificial intelligence (AI) in agriculture in Africa

The African continent, endowed with vast agricultural potential, faces numerous challenges in land use and agricultural productivity (Nhemachena et al., 2020; Rutherford, 2017). Traditional farming methods, limited access to modern technology, and unpredictable climate patterns pose real threats to the agricultural sector, which is responsible for the livelihoods of millions (Nhemachena et al., 2020). The use of artificial intelligence (AI) may provide an opportunity for transformative solutions to these longstanding issues, presenting a chance to revolutionise agriculture and land use across Africa (Sampene et al., 2022).

AI technologies can significantly assist farmers in making data-driven decisions that optimise crop yields and resource use (Adisa et al., 2019; Ikudayisi et al., 2022). Through the integration of AI-powered drones and satellite imagery, farmers can monitor crop health, soil conditions, and weather patterns in real-time (Ikudayisi et al., 2022; Kouadio et al., 2018). This continuous flow of information enables early detection of pest infestations, diseases, and water stress, thereby mitigating potential losses and improving overall farm management (Gorlapalli et al., 2022; Kiobia et al., 2023). Moreover, AI can facilitate the development of intelligent irrigation systems that conserve water and energy. These systems may use machine learning algorithms to analyse soil moisture data and weather forecasts, ensuring that crops receive the optimal amount of water. This is particularly beneficial in regions facing water scarcity, where efficient water management is critical for sustainable agriculture (Ikudayisi et al., 2022).

AI may also play an essential role in supporting land use planning and policy-making. By analysing large datasets on land use patterns, population growth, and environmental impact, AI can help governments and organisations design strategies that balance agricultural expansion with environmental conservation. Predictive modelling can identify areas suitable for agricultural development while preserving biodiversity and preventing land degradation (Foster et al., 2023; Gwagwa et al., 2020; Omeiza, 2019).

Furthermore, AI-driven platforms can enhance market access for smallholder farmers by providing real-time price information, demand forecasts, and supply chain optimisation. This connectivity empowers farmers to make informed decisions about crop selection, marketing, and distribution, ultimately increasing their income and reducing post-harvest losses (Songol et al., 2021). Figure 1 presents a general overview of areas AI may support in African countries.

It is seen that AI may be deployed in a variety of ways, offering concrete support to agriculture in Africa.

There are various examples of how AI is being used in African countries. Many African countries are bypassing traditional infrastructure development (like landlines) in favour of mobile and digital technologies. This shift allows for rapid adoption of AI, especially in sectors like mobile banking and telemedicine. Also, Africa has a young and tech-savvy demographic, which fosters innovation and entrepreneurship. This population is increasingly engaging with AI technologies, creating a vibrant startup ecosystem. Figure 2 provides an overview of some of the current applications in a set of African countries, namely Ethiopia, Ghana, Kenya, Nigeria, Rwanda, and South Africa.

The potential for increased use of AI in Africa is significant in several regions, primarily driven by factors such as growing mobile connectivity, improved internet access, and a young, tech-savvy population. Countries like Kenya and Rwanda are leading in tech innovation in East Africa. Kenya has a vibrant tech ecosystem with a focus on mobile technology and fintech, while Rwanda is investing in innovative city initiatives. In West Africa, Nigeria, particularly Lagos, is emerging as a tech hub with a focus on startups and digital solutions. The demand for fintech, agritech, and health tech applications is high. In North Africa, nations like Egypt and Morocco are seeing growth in AI applications in sectors like e-commerce, finance, and logistics, bolstered by government support for tech startups. In Southern Africa, South Africa has a well-established tech infrastructure and is experimenting with AI in various sectors, including finance, security, and manufacturing".

These examples highlight the diverse ways in which AI is being leveraged to transform agriculture in Africa, addressing various challenges and driving sustainable growth in the sector.

Risks of using AI in agriculture and how to address them

Using AI to support land use and agriculture in Africa holds significant promise, but it also comes with several risks that need to be carefully managed. The first one is related to data quality and availability (Table 1). AI systems rely on large volumes of data. The AI models may produce unreliable results if the data is inaccurate, incomplete, or outdated. Also, there is a risk associated with data scarcity. Many regions in Africa lack comprehensive and up-to-date agricultural and environmental data, which can limit the effectiveness of AI solutions (Gikunda, 2024; Mark, 2019).

Moreover, AI models can inadvertently incorporate biases in the training data, leading to unfair outcomes. For example, certain crops or regions may be favoured over others, exacerbating existing inequalities (Table 1). Cultural sensitivity may also be a risk since systems developed in other parts of the world might not account for local cultural practices and agricultural techniques that are singular to African countries, as well as preferences (Foster et al., 2023; Gwagwa et al., 2020).

The availability of technological infrastructure may also pose a challenge, due to limited internet connectivity, lack of reliable power supply, and inadequate technological infrastructure. These can hinder the deployment and use of AI solutions in rural areas. Finally, there is a risk associated with limited accessibility (Table 1).

Smallholder farmers, who form the backbone of agriculture in Africa, may not have the resources, education, or training to effectively use AI technologies (Arakpogun et al., 2021; Gwagwa et al., 2020).

There are also significant economic and social impacts which cannot be overlooked. One of them is the potential displacement of labour. Automation and AI-driven efficiency improvements might displace agricultural labour, leading to unemployment and social unrest (Gruetzemacher et al., 2020). AI may also worsen economic disparities, since wealthier and more developed regions or individuals may benefit more from AI advancements, widening the financial gap between rich and poor communities (Goralski et al., 2020). Some environmental concerns are seen since AI-driven optimisation might promote monoculture practices, reducing biodiversity and increasing vulnerability to pests and diseases. AI recommendations might not always align with sustainable practices, potentially leading to over-exploitation of natural resources such as water and soil (Ditzler et al., 2022; Sparrow et al., 2021).

Finally, the rapid pace of AI development can outstrip the creation of appropriate regulatory frameworks, leading to potential misuse or unintended consequences. Issues related to data ownership, intellectual property rights, and benefits sharing, along with data security and privacy issues, need careful consideration to ensure the fair use and distribution of AI technologies (Tzachor et al., 2022; Uddin et al., 2024).

These risks can be addressed by a variety of measures. A primary, fundamental step, the establishing clear regulatory frameworks for AI deployment, to guide ethical and responsible use.

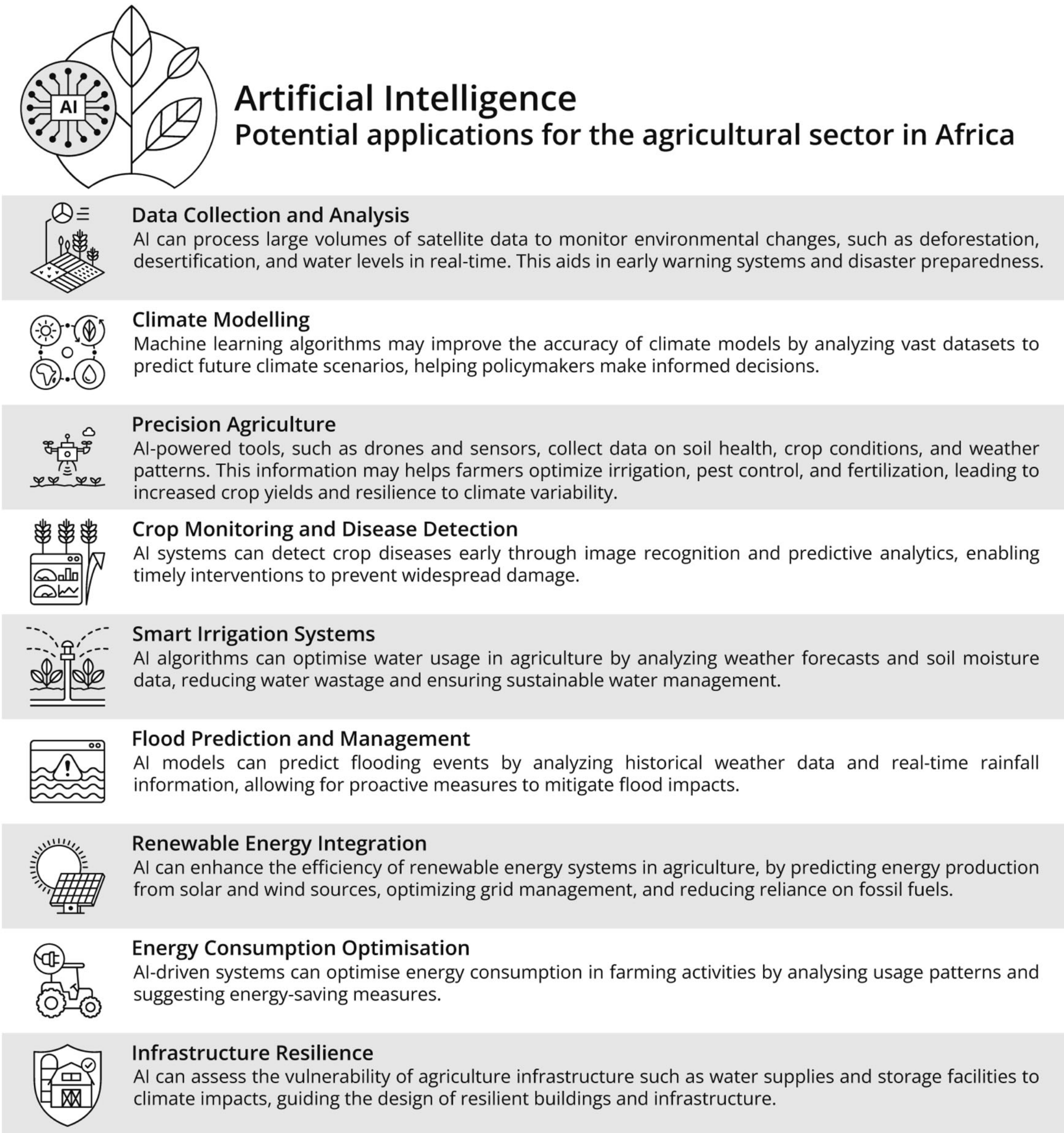

Fig. 1 Potential applications of AI in agriculture in Africa.

Policy-makers should develop guidelines that balance innovation with moral considerations, ensuring AI applications do not exacerbate existing inequalities. Promoting multi-stakeholder engagement and international collaboration can also enhance governance structures.

A further measure is to ensure the privacy and security of data collected by AI systems. Establishing robust data governance frameworks and cybersecurity measures is necessary to protect sensitive information from unauthorised access and misuse. This includes implementing encryption, access controls, and regular audits to maintain data integrity. In addition, it is important to use diverse and representative datasets, employ bias detection and correction techniques, and ensure transparency in AI algorithms. Engaging local experts and communities in the development process can also help in creating context-specific and fair solutions. Moreover, since the deployment of AI technologies requires reliable infrastructure, including robust internet connectivity and computational power, which may be lacking in many African regions, investments in digital infrastructure and capacity building are necessary, to overcome these limitations. Developing low-resource AI models that can function effectively with limited data and computational resources can also enhance accessibility.

The high costs associated with AI development and deployment can be a barrier for many African communities. Securing sustainable funding through public-private partnerships, international aid, and innovative financing mechanisms can help to address it. Moreover, promoting open-source AI tools and collaborative platforms can reduce costs and foster innovation.

There is also a perceived need to address the shortage of skilled AI and climate science professionals in African countries. This can be achieved through education and training programmes, knowledge transfer initiatives, and fostering collaboration between academic institutions, governments, and industry. Building local expertise ensures that AI solutions are tailored to the unique challenges faced by African communities.

Conclusions

As this article has shown, there is a significant potential for the use of artificial intelligence in support of efforts to pursue climate

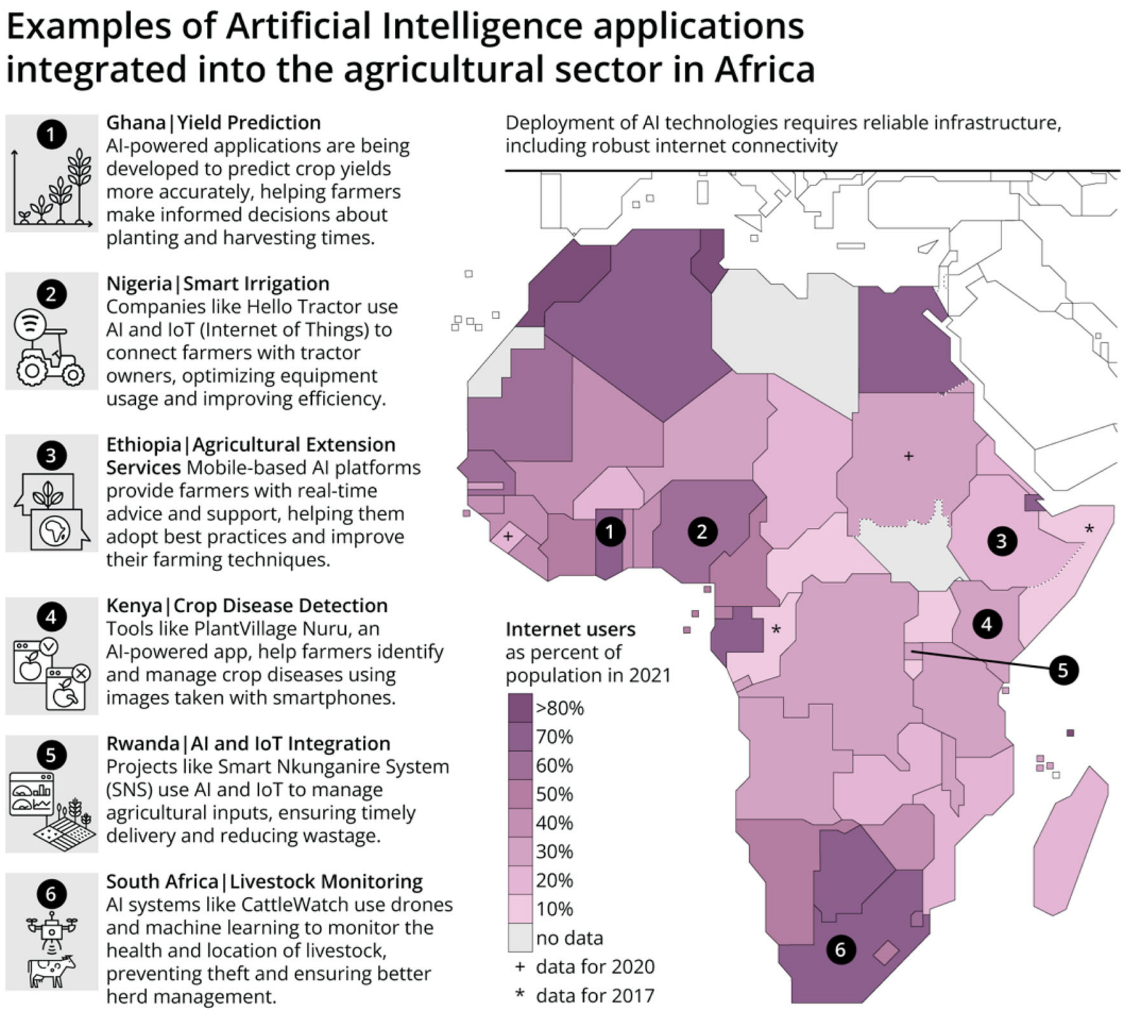

Fig. 2 Examples of AI applications integrated into the agriculture sector in Africa.

Table 1 Risks of AI use in Africa and measures to mitigate the risks.

Risk of AI use	Description	Mitigation measures
Data privacy and security	Concerns over unauthorised data use and breaches.	Implement strong data protection laws and regulations; promote data literacy.
Bias and discrimination	AI systems may perpetuate existing biases, leading to unfair outcomes.	Ensure diverse datasets; conduct regular audits and impact assessments to identify and mitigate biases
Lack of infrastructure	Insufficient digital infrastructure can hinder AI deployment.	Invest in digital and telecommunications infrastructure; encourage public-private partnerships.
Job displacement	Automation may lead to job losses in certain sectors.	Promote reskilling and upskilling programmes; invest in education to prepare the workforce for AI-related jobs.
Regulatory challenges	A lack of clear regulations can lead to the misuse of AI technologies.	Develop comprehensive AI policies and frameworks that promote innovation while ensuring accountability
Limited access to technology	Disparities in technology access can create inequities.	Increase access to technology through government programmes and public-private collaborations; invest in affordable internet initiatives.
Ethical concerns	Concerns about the ethical use of AI, including surveillance and autonomy.	Establish ethical guidelines for AI development and use; engage stakeholders in discussions about ethical practices.
Dependency on outsiders	Over-reliance on foreign technologies may hinder local innovation.	Encourage local AI development by supporting startups and research initiatives; foster knowledge transfer.
Knowledge and skills gap	Limited expertise in AI technologies and implementation.	Expand education and training programmes in AI and data science; promote collaboration with academic institutions.

By proactively addressing these risks, Africa can harness the potential of AI to support effective and equitable climate change adaptation.

change adaptation in an agricultural context in African countries, But there are also various risks. Addressing these risks requires an inclusive approach involving farmers and stakeholders from government, industry, academia, and local communities. By fostering collaboration, ensuring equitable access, and prioritising sustainable and ethical practices, the benefits of AI in land use and agriculture can outweigh the risks, and help farmers´ communities face the many challenges and risks they are currently exposed to (Chaterji et al., 2020; Tzachor et al., 2022; Uddin et al., 2024).

Data availability

This article didn't use any empirical data.

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WL conceptualised the paper and provided editorial input. He authored sections of the paper and provided editorial guidance throughout the process. GJG assisted in the writing and editing of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

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