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KEYNOTE PAPER

Responsible Artificial Intelligence for Agriculture and Food Systems: Challenges and Opportunities in Africa

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1.0 Introduction

It is with great pleasure and honour that I present this keynote paper entitled "Responsible Artificial Intelligence for Agriculture and Food Systems: Challenges and Opportunities in Africa" during the 28th Annual Conference of the Agricultural Extension Society of Nigeria (AESON) held at the ARMTI Training Institute, Abuja, Nigeria from 14-17 May 2023. I am particularly enthused about the choice of this year's Conference theme which is the "Changing Paradigms in Agricultural Extension". This is because the extension system continuously evolves considering that the societal challenges and farming needs also change with time.

. This can be achieved through the development, deployment, and scaling of homegrown and responsible AI research, innovations, and policy to tackle pressing challenges in agriculture and food systems in Africa. That notwithstanding, it is important to note that any new technology will also come with its own challenges and opportunities.

2.0 What is Artificial Intelligence?

Artificial Intelligence (AI) is the capacity of a machine to perform cognitive functions associated with human minds, such as perceiving, reasoning, learning, interacting with the environment, solving problems, and even exercising creativity (Manyika et. al., 2017). AI stands out as one of the emerging technologies with great potential to transform the agriculture and food systems (AFS) and ensure that all aspects of food security including food availability, access, utilization, and stability are achieved even for small-scale farm enterprises in Africa thereby helping to address the relevant sustainable development goals (SDGs #) numbers 1 (no poverty), 2 (zero hunger), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 13 (climate action), and 15 (life on land).

2.1 What is responsible Artificial Intelligence?

Responsible AI is the practice of designing, developing, and deploying AI that is lawful, ethical, robust, societal, and environmentally friendly, with good intentions to empower people. Responsible AI (RAI) is the only way to mitigate AI risks. Eight core principles underpin RAI namely, 1) ethical purpose and societal benefits, 2) privacy, 3) open data and fair competition, 4) safety and reliability, 5) fairness and non-discrimination, 6) transparency and explainability, 7) AI and intellectual property rights, and 8) accountability.

3.0 Rationale for Responsible Artificial Intelligence in Agriculture and Food Systems in Africa

With the current geometric rise in Africa's population estimated to reach about 2.6 billion by 2050 from the current 1.4 billion and a growth rate of more than 2.5% p.a. (Population of Africa, 2019), it becomes imperative that AFS are reviewed to embrace innovative approaches for sustaining and improving the system from production to utilization.

The introduction of AI for AFS is enabled by other technological advances such as big data, robotics, machine learning (ML), Internet of Things (IoT), availability of affordable sensors and cameras, drone technology, and even wide-scale internet coverage on geographically dispersed fields (Eli-Chukwu, 2019). Despite the growth of movements applying ML, IoT, and AI among other tools to solve the AFS challenges, there remains the need to identify how these tools may best benefit Africa under its peculiar circumstances.

4.0 Potential Thematic Areas where Responsible Artificial Intelligence can be Applied in Agriculture and food Systems' Research and Innovation in Africa

Four dimensions of **food security: availability, access, use/utilization, and stability** as the key thematic areas where RAI can be applied in AFS.

Food Availability: This addresses whether or not food is actually or potentially physically present, including aspects of production, food reserves, markets and transportation, and wild foods. RAI can therefore be applied under this thematic priority in the following ways:

1. **Prediction of crop yields -** tools to help farmers make ideal decisions in crop yield forecasting and improve smart farming practices that lead to higher yields.
2. **Prediction of soil management properties -** tools for understanding soil conditions and how to boost its performance to support productivity.
3. **Farm management systems** - tools for precision agriculture to detect and perform farm management operations such as planting, irrigation, pollination, weeding, fertilizer application, harvesting, etc.
4. **Pest and disease detection** - early detection of pests and diseases in the farm and eventual prevention or control.
5. **Smart mechanization** - tools to reduce drudgery in agriculture and minimize inputs, highly autonomous and intelligent machines and agribots.
6. **Livestock surveillance** – tools for monitoring illnesses, injuries, and even pregnancies among the herds.

Food Access: This addresses whether or not households have sufficient access to quality, quantity and diversity of nutritious foods. RAI can therefore be applied under this thematic priority in the following ways:

1. **Food demand monitoring** - tools for real-time monitoring and control of changes in food demand.
2. **Supply chain management** - tools for monitoring food origin, quality, and safety that afford transparency, trust, certification, and traceability of the food product supply chain from farm to fork.
3. **Food retailing** - tools for predicting consumer demands, perceptions, and buying behaviours.
4. **Transportation and storage** - preservation of food product quality, to ensure safe food products and to minimize product damage.
5. **Inventory management -** prediction of daily food demand and to ensure that there are no inventory-related problems.

Food Utilization: This addresses whether or not households are maximizing the consumption of adequate nutrition and energy determined by knowledge and habits as well as the ability of the human body to take food and convert it. RAI can therefore be applied under this thematic priority in the following ways:

1. **Modern processing techniques** - software algorithms for enhancing heating, cooling, milling, smoking, cooking, and drying to ensure high quality and quantity of agrifood products and, at the same time, avoid overutilization of resources and wastages.
2. **Minimizing postharvest losses -** tools for preservation, processing, and safe storage of foods.
3. **Societal impacts** - ecology, infrastructure, livelihoods, nutrition, social systems, crisis and cultural practices of the food systems.

Food Stability: This addresses whether or not households are food secure at all times. Stability issues refer to short-term, medium to long-term instabilities that can be caused by climatic, economic, social, and political factors. RAI can therefore be applied under this thematic priority in the following ways:

1. **Climate and weather prediction** - tools to help farmers increase yields and profits without risking the crops or livestock from climate vagaries.
2. **Decision support** - support systems to enhance farmers' choices in crop cultivation, consumer preferences, fashion, and trends.
3. **Yield prediction** - prediction of gaps between food production, supply, and consumption to inform national agricultural policies, tracking and tracing agricultural commodities along transportation routes.
4. **Disaster prediction –** tools that can identify impending disasters such as pests and diseases invasions, locust invasions, etc. and enable farmers to mitigate them.
5. **Collective decisions** - modelling social interactions, informing policy, and designing markets.
6. **Training, education, and knowledge exchange** - tools for enhancing extension service delivery and information sharing.
7. **Access to production factors –** tools for enhancing access to factors of production such as land, inputs, capital, labour, etc. especially for marginalized groups like women, youth, and persons with disabilities (PWDs).

5.0 Challenges to the development, deployment, and scaling of Responsible AI in AFS in Africa

Some of these challenges are:

1. **Lack of diverse datasets specific to localized priorities**: The lack of publicly available datasets contextualized in Africa and Africa's agriculture and food systems to train in algorithms has hampered the use of precision agriculture tools on the continent. Published datasets do not meet the demand for specialized datasets that are specific to local issues.
2. **Privacy issues**: There are privacy concerns arising from the data and images captured by satellites and drones to train algorithms. Existing laws and legislations in most African countries are restrictive, while datasets may be unlawfully used.
3. **Low digital literacy**: Farmers may not know how to access or use the available AI applications or how to use these technologies to support precision agriculture.
4. **Lack of supporting research infrastructure**: AI development and deployment only thrive in the presence of requisite research infrastructure such as internet availability, power supply, and large-scale computer facilities including high-throughput, high-performance, and cloud computing. Others include data storage facilities, repositories, stewardship and security software shared code libraries, mechanisms for access, such as networks and user authentication systems, and the people i.e., the users, and the experts who develop and maintain these powerful resources.

5. **Gender gaps in AI in Africa**: With the advent of technology, the gap between men and women is widening, if not worsening. In Africa, the percentage of men-to-women engagement in AI stands at 78%:22% respectively.
6. **Environmental concerns**: AI training is an energy-intensive process. New estimates indicate that training a single AI will produce 284 tonnes of carbon dioxide emissions. This is five times the lifetime emissions of an average car (Coleman et al., 2019). Model training and activities must be carried out responsibly with proper carbon footprint reporting.
7. **Poor funding and investments in R&D in Africa**: With investment of less than 1% of GDP in research and development (R&D) in Africa, the sustainability of AI development may be hampered due to a lack of adequate funds.
8. **Lack of awareness**: Farmers and expected users of AI are not yet aware of its potential to improve food security in Africa.
9. **Ecosystem issues**: The linkage between research and the industry is still poor to foster effective linkage of actors in the development, deployment, and scaling of AI in AFS's value chain.

6.0 Opportunities for the development, deployment. and scaling of responsible AI in AFS in Africa

The challenges discussed in Section 5.0 above provide opportunities. Some of these opportunities are highlighted below:

1. **Availability of data**: AI systems require massive training on data sets because applications effectively "learn" from available information in a manner similar to the way humans do, there is, therefore, a high requirement for large amounts of high-quality data. This creates the opportunity for data scientists to be trained to acquire relevant skills in building data banks for Africa's homegrown AI development and deployment. Universities and various institutions can reframe their curriculum to incorporate the teaching and storage of big data unique to Africa for the deployment of AI. Providing such a data bank will ensure that AI in Agriculture and food systems are responsible and homegrown.
2. **Investment in new technologies**: AI technologies have put pressure on organizations to invest in new technologies that can quickly process data and run complex algorithms. These investments in infrastructure will enable African organizations to be abreast of their peers and promote homegrown and responsible AI development, deployment, and scaling. Investments in technological infrastructure also translate to increased R&D investments that lead to sustainable development.
3. **Increased technical skills**: AI development, deployment, and scaling require technical skills and expertise which are now growing on the continent to be able to fully harness the opportunities that it presents. Expertise in statistics, probability, predictions, calculus, algebra, Bayesian algorithms, and logic is required. Others include programming, logic, data structures, language processing, and cognitive learning theory etc.
4. **Remote agricultural operations**: AI can help farmers reduce the cost of carrying out and monitoring farm work for large-scale farming. AI-supported smart tractors and robotics (agribots) can be deployed to perform certain functions, e.g., harvesting large volumes of crops, possibly at a higher speed and volume than human labour would. In livestock farming, drones mounted with cameras or sensors can gather information on the number of animals, unusual livestock movements, and animal health among others.
5. **Weather forecasting**: AI can use the data from past weather events to predict future weather occurrences and hence provides information on the best time for planting, fertilizing, spraying, irrigating, harvesting, marketing, and processing, among other things.
6. **New policies and institutions**: AI has offered the opportunity to develop new policies, legislations and institutions that will be responsible for guiding AI research and development in Africa. These policies and institutions will help to ensure that the type of AI development pursued in Africa is homegrown, responsible, and meets the needs of African people and the environment.
7. **Increase youth and gender inclusion**: AI offers great opportunities for youth and gender engagement in the new technology. It will give youth and female scientists as well as AI leaders in business and society more chances and thus highlight opportunities for women in AI and remove the negative stereotypes about females not belonging to science, technology, engineering, and mathematics (STEM).

7.0 Ten (10) Research and Innovation Projects Undertaken by the African Technology Policy Studies Network (ATPS) on Responsible AI in Agriculture and Food Systems in Africa

Project 1: Monitoring and Artificial Intelligence Tools for Smart Agriculture (Cape Verde).
Goal: To use the Internet of Things and Artificial Intelligence solutions suitable for Cape Verde to increase the production level that allows mitigation and increased resilience in the face of climate change.

Project 2: Development of Machine Learning Model for Crop Pests and Diseases Diagnosis Based on Crop Imagery Data (Tanzania)
Goal: To develop a Machine Learning model for early detection of Common bean and Irish potato diseases in the Southern Highlands regions of Tanzania.

Project 3: Enhancing Farm-scale Crop Yield Prediction using Machine Learning Models for Internet of Agro–Things in Tanzania.
Goal: This project aims to develop reliable and reusable ML-driven crop yield prediction models using historical meteorological data, satellite data and proximal sensor data to enhance crop yield predictions in Tanzania.

Project 4: Using AlI to enhance the Production, Management and Marketing of Nsukka Yellow Pepper (Capsicum Chinese Nsukkadrilus), (Nigeria).

Goal: This project aims to develop and deploy Artificial Intelligence to improve the productivity and yield of Nsukka Yellow Pepper by strengthening the resilience of farmers in adapting to climate change, applying mitigation strategies, and thus empowering the women and youths.

Project 5: Scaling Smartphone-Based Tools for Early Crop Diseases Detection & Monitoring (Uganda)
Goal: The project aims to create positive impacts on the livelihoods of smallholder farmers b)y availing them with automated disease diagnosis tools for in-field and real-time feedback thus improving food security and production.

Project 6: Pest Occurrence Early Warning System and Diagnostic Tool Development using Geoinformation and AI: A Case Study of Tomato Leaf Miner (Tuta Absoluta), and Whiteflies in Kenya
Goal: The project aims to develop a Spatial AI web Tool to detect, identify, and monitor leaf miners (Tuta absoluta) and whiteflies to allow for the integration and implementation of Integrated Pest Management Solutions in smallholder tomato vegetable farms in Machakos county, Kenya, a

Project 7: Empowering Smallholder Farmers (SHF) in Busia County Using Low-Cost IoT and AI Tools (Kenya)
Goal: The project aims to provide localized and actionable gender-responsive climate information services to help rural smallholder farmers become climate resilient and increase yields and profits without risking the crops or livestock from climate vagaries.

Project 8: Building the AI for soil moisture and nutrient monitoring under irrigated agriculture among smallholder farmers, academic and agriculture experts in Malawi.
Goal: The project aims to build artificial intelligence for soil moisture and nutrient monitoring under irrigated agriculture to improve food availability and stability being challenged by poor water and nutrient management among smallholder farmers and agriculture experts in Malawi.

Project 9: TOLBI AI, an AI-based digital tool for smart, sustainable, and efficient agriculture (Senegal)
Goal: The project aims to provide farmers, producers and public organizations with real-time yield forecasting information and a field management platform to monitor plant health, fertilization, and water requirements.

Project 10: Detection of Crop Pests and Diseases on Web and Mobile Devices Using Deep Learning (Ghana)
Goal: The project aims to develop a mobile/web AI-based system with which farmers can detect crop illnesses and pests in the early stages.

Conclusion

Responsible AI is an innovative pathway in leapfrogging Africa's Agriculture and Food Systems to reduce hunger and increase Africa's GDP. Efforts in climate change adaptation and resilience will be enhanced through the application of AI in the four components of food security namely, availability, access, utilization, and stability. Africa and African research and development environment must be equipped with enabling research infrastructure, policy reforms, and institutional, and financial support to develop and deploy an inclusive, robust, and ethically responsible AI in AFS. Research institutions must form a strong synergy with the private sector and CSOs to effectively develop, deploy, and scale responsible AI Systems.

Policy Recommendations

Recommendation 1: Strengthening the capacity to develop, deploy, and upscale AI in Agriculture and food systems. There should be an active drive for data acquisition relevant to Africa's environment to ensure just application of data to increase the capacity to deploy AI in agriculture and food systems. African governments should establish an inclusive and protected data bank with crop, animal, soil, weather, and market information. There is a need to build the capacity at individual, institutional and systemic levels e.g., through curriculum reforms to support capacity development in AI systems.
Recommendation 2: Strengthening Institutional synergy and collaboration. Responsible AI deployment needs the collaboration of relevant institutions; academia, private AI firms, farmers, government, primarily private and public organizations. Joint research and development efforts among the ecosystem actors in AI for AFS are recommended.
Recommendation 3: Increased funding of Science, Technology, and Innovation. Increased investments in agricultural R&D at the continental and national levels will support STI development in general. The 1% investment in R&D by African governments remains a better option. Private sector investments and philanthropies will drive effective development, deployment, and scaling of AI technologies and innovations in tackling pressing societal challenges in AFS in Africa.
Recommendation 4: Strengthening the STI pro-AI Policy in Africa. African governments should take a proactive approach and implement AI-friendly regulations, policies, and initiatives. Africa must develop the right policy and institutional frameworks that can create the enabling environment for the development, deployment, and use of responsible AI in Africa's Agriculture and food.

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