African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 4, 2024 (pp. 172-188)
www.abjournals.org

MKULIMAGPT: EQUITABLE AI USE VIA A SWAHILI CHATBOT FOR MAIZE FARMING SYSTEM IN TANZANIA

Theofrida J. Maginga[1,2*], Steven Jofley Kutuku[1], Hamdun Fadhil Hamza[1], Gibson Gosbert Mulokozi[1], and Jimmy Nsenga[2]

[1]Sokoine University of Agriculture (SUA), Morogoro, Tanzania.

[2]African Centre of Excellence in Internet of Things (ACEIoT) - University of Rwanda (UR), Kigali, Rwanda.

[*]Corresponding Author's Email: theofrida.maginga@sua.ac.tz

Cite this article:

Maginga, T. J., Kutuku, S. J., Hamza, H. M., Mulokozi, G. G., Nsenga, J. (2024), MkulimaGPT: Equitable AI Use Via a Swahili Chatbot for Maize Farming System in Tanzania. African Journal of Agriculture and Food Science 7(4), 172-188. DOI: 10.52589/AJAFS-VERNTB5I

Manuscript History

Received: 11 Jun 2024

Accepted: 14 Aug 2024

Published: 17 Oct 2024

ABSTRACT: *The maize sector in Tanzania is crucial for the country's food security and economic stability. However, farmers face various challenges, including diseases that reduce yields and limited access to information. To address this, an innovative solution called MkulimaGPT has been developed, it is a text and voice chatbot that uses generative Artificial Intelligence (AI) technology and is accessible through WhatsApp. The platform offers real-time agricultural guidance in Swahili, overcoming language and literacy barriers. It is available through a local phone number and designed to cater to Tanzania's digital landscape by utilizing the widespread mobile network. MkulimaGPT blends generative AI's capabilities with the comprehensive agricultural knowledge base, ensuring its advisory services are contextually rich and technically astute. It is an example of inclusive AI and bridges the gap between farmers and extension services, fostering inclusivity for marginalised groups, particularly women, with a commitment to deliver real-time, and actionable insights for Tanzania's maize farming.*

KEYWORDS: Equitable AI, Agricultural Chatbot, Maize Farming, Tanzania, Generative AI Technology.

Article DOI: 10.52589/AJAFS-VERNTB5I
DOI URL: https://doi.org/10.52589/AJAFS-VERNTB5I

African Journal of Agriculture and Food Science
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INTRODUCTION

Maize is an essential crop in Tanzania, serving as a staple food and a cornerstone of the agricultural economy. However, the sector faces significant challenges, including Maize Lethal Necrosis and Northern Corn Leaf Blight diseases, which cause annual yield losses of up to 40% (Minot & Minot, 2014). These issues pose a serious threat to the nation's food security and the livelihoods of its farmers. Adding to the difficulty is the limited availability of agricultural extension services to support smallholder farmers in managing and intervening in maize crop disease, with a single extension officer serving up to 500 farmers (Wambura, 2015). This makes it challenging to disseminate critical farming knowledge and practices effectively. Besides that, gender disparities also play a role, as social norms often hinder communication between male extension officers and female farmers, leading to a significant information gap (Q Anugwa, 2018). (Jiggins et al., 2000), reported that the selection criteria of the contact farmers using title to land, cooperative membership, and an assumption of women's role in farming has left women constantly disadvantaged in accessing training opportunities and information in agriculture. While access to training materials is still a challenge to most farmers in sub-Saharan countries, a study shows that education is a very important tool to help farmers advance different techniques for advancing crop yield, promoting the harvested crops, and marketing purposes. Most developed countries that perform better on cultivation processes, such as Spain, Romania, Italy, and Belgium, have continued launching educational services to improve sustainable social, environmental, and economic development (Kowalska et al., 2016).

Artificial Intelligence (AI) is increasingly being integrated into agriculture through smart farming initiatives, offering farmers access to vital information and recommendations on optimal practices for improving yields (Ryan, 2023). AI impact spans from enhancing crop yield and quality to optimizing resource usage. AI applications are making inroads globally, from analyzing land use with high-precision satellite imagery to predicting crop diseases through real-time monitoring. This wave of technology is not only drawing widespread attention in agri-tech but also attracting investments to foster innovation and growth (Javaid et al., 2023). Among these innovations, AI chatbots stand out as a particularly promising tool. They have been implemented in various agricultural contexts around the globe, offering a solution to some of the most pressing challenges faced by the sector (van der Burg et al., 2022). By delivering personalized advice on what actions to take, when, and how, these chatbots significantly contribute to the advancement of smart farming practices, promising a more efficient and productive agricultural future.

In India, the "AgroConnect" system provides crop management advice that is tailored to the local area (Sharma et al., 2008), at the same location another chatbot in for farmers has been developed named Agrimart. This is an Agrodirect selling software featuring a voice-based chatbot to aid agriculturists and connect farmers with retailers. The application aims to streamline agricultural transactions by reducing reliance on middlemen. It promotes agricultural products such as fruits and vegetables and also functions as a database for farmer information. Its primary goal is to establish a system that facilitates direct sales, enabling farmers to sell their produce directly to consumers in a fair and profitable manner (Priyankadevi et al., 2022). "While in Canada, "AgronomoBot" is utilized to create a natural conversation between individuals, answering queries and performing tasks, in a manner that gives the impression of speaking with another person and not with a computer program. The bot was developed to search and display data obtained from a Wireless Sensor Network deployed in a vineyard (Mostaço et al., 2018). In Chiang Mai, a LINE chatbot helps farmers grow lettuce

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using IoT and sensors. Farmers scan a QR code to access the chatbot and get insights on crop cultivation procedures, irrigation, fertilization, pest control, and more. The chatbot also transfers field information and recommendations. It has a 96% satisfaction score among farmers (Suebsombut et al., 2023). In Uyo, Nigeria, the chatbot has also been developed to enable the government to engage with farmers and gather feedback. Moreover, the chatbot utilizes a machine-learning approach to facilitate knowledge sharing (Usip et al., 2022). The global trend towards digital agricultural advisories is evident through these initiatives.

Meanwhile, the adoption of chatbot technologies in various regions, including Tanzania, has been hindered by a lack of linguistic and cultural customization, which is critical for their successful implementation (Coniam, 2014). This challenge is part of a broader issue faced by farmers in developing countries: limited access to crucial information that can help improve their agricultural practices. To address this issue, several solutions have been proposed. These include creating forums that enable farmers to interact with experts and peers, thereby facilitating the exchange of valuable knowledge and experiences (Misaki et al., 2016). Additionally, peer education programs utilizing participatory videos have been introduced to provide practical knowledge (Paltasingh & Goyari, 2018), and mobile applications have been developed to offer farmers a direct channel for accessing agricultural advice and market information (Sharma et al., 2008). Despite these initiatives, ensuring that agricultural experts meet the high demand, operate continuously, respond promptly, and manage their workload effectively remains a significant challenge (Maker, 2014). This underscores the need for innovative solutions that not only bridge the information gap but also ensure sustainability and scalability in delivering expert support to farmers.

Building on the efforts to overcome information access challenges in agriculture, the emergence of transformer architecture marks a significant leap forward in the field of artificial intelligence. The development of the GPT series, with its highly efficient and adaptable language models, showcases the immense potential of AI to revolutionize a wide array of applications. This includes not just text generation, translation, and summarisation but also providing personalised, real-time advice to farmers. Specifically, large language models like Generative Pre-Trained Transformers (GPT-3 and GPT-4) offer a scalable solution that can significantly improve agricultural practices by making expert advice accessible to farmers anywhere and anytime (Ray, 2023). The potential of this innovative chatbot technology to globally enhance agricultural decision-making and operational efficiency is substantial (Raj et al., 2023). In particular, research conducted by (Zhao et al., 2023) delves into ChatGPT's capabilities in the precise classification of agricultural texts, underscoring its effectiveness in advancing practices related to weather forecasting, pest and disease identification, and market analysis. Such advancements highlight the feasibility of using ChatGPT to support critical agricultural decisions.

Although the adoption of this technology in Tanzania and other developing countries is still in its initial stages, the specific applications of these chatbots promise a revolutionary impact on agricultural practices (Gatzioufa & Saprikis, 2022). By harnessing the power of advanced AI language models, chatbot technologies are poised to become a vital tool in the global effort to support farmers in developing countries. Hence, this work presents MkulimaGPT, an AI chatbot created to aid Tanzanian farmers, particularly in maize crop management. Named from the Swahili word for 'farmer', MkulimaGPT comprises a localized agricultural knowledge with the sophisticated capabilities of OpenAI's ChatGPT. By integrating the Swahili language and cultural nuances, MkulimaGPT ensures effective communication with farmers. Its advanced

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Natural Language Processing (NLP) technology and user-generated knowledge base ensure contextually relevant responses. As MkulimaGPT evolves, it refines the AI model with user feedback and emerges as a dynamic, scalable AI tool. Future enhancements, including IoT and weather analytics, anticipate a significant transformation in Tanzanian agricultural practices, underlining AI's potential to address specific, localized needs.

This paper is organized into the following sections, each providing a comprehensive analysis of the MkulimaGPT Swahili Chatbot initiative. Section 2, which is a Methodology, introduces the MkulimaGPT Development Framework. This section outlines the technical and conceptual foundations of the platform before delving into the OpenAI GPT Model in Section 2.2. This section demonstrates how the chatbot utilizes its advanced natural language processing capabilities. Section 2.3 explores the role of the Twilio Application Programming Interface (API) in facilitating seamless interactions between farmers and the chatbot. Section 2.4 describes the Maize Farming Knowledgebase, the foundation for the chatbot's advisory services. Section 3 of the paper comprises Results and Discussion; in this part, we examine user interactions and bot responsiveness in Section 3.1. We then explore the criteria for evaluating the chatbot's performance in Section 3.2. Subsequent sub-sections 3.3 and 3.4 discuss the impact of MkulimaGPT on farmers' decision-making processes and analyze patterns in question types and response quality. The section concludes with assessing the platform's performance, highlighting its strengths and identifying opportunities for further enhancements. Finally, in the conclusion section, we synthesize the findings and contributions of this research. We emphasize the significant progress made in applying AI to address the informational needs of the agricultural community in Tanzania.

METHODOLOGY

Mkulimagpt Development Framework

The development framework integrates OpenAI, Twilio, and WhatsApp to create a conversational service for maize farmers. The MkulimaGPT framework has been specifically developed to bridge the knowledge gap among farmers in Tanzania, leveraging a mobile interface with a particular emphasis on the WhatsApp platform. This choice is strategic, considering the substantial penetration of internet services in the country, as evidenced by the 34 million users subscribed to internet services as of June 2023 (TCRA, 2023), representing approximately 50% of the total population, according to the 2022 census (CENSUS, 2023). This digital landscape provides a fertile ground for adopting technology-driven agricultural advisories among farmers.

A recent study done by (Almasi et al., 2023) shed light on the significant access to social media platforms among small-scale chicken farmers (SSCFs) in Tanzania, revealing a notable inclination towards digital communication tools for accessing market information. Specifically, research indicates that 63.08% of SSCFs utilize WhatsApp, among other social media platforms such as Facebook and YouTube. These statistics not only underscore the high level of social media engagement among SSCFs but also highlight the potential for platforms like WhatsApp to serve as effective channels for delivering crucial agricultural information. The MkulimaGPT's focus on WhatsApp takes advantage of this high level of access and engagement, aiming to significantly improve the dissemination of agricultural knowledge and support among farmers. The approach taken involves building technology on top of the existing

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WhatsApp messenger application. This is an effective strategy for ensuring easy adoption and acceptance due to its utilization of the familiarity, infrastructure, and user base of the underlying technology. This approach minimizes the learning curve for users and reduces the need for extensive retraining or new infrastructure investments. It also allows for incremental improvements and seamless integration, as users can leverage their existing knowledge and systems. Additionally, it enhances trust and credibility, as the new technology inherits the reliability and performance of the established one, thereby facilitating smoother transitions and broader acceptance (Chan et al., 2017). The technological foundation of MkulimaGPT lies behind several curated stacks designed for scalability and ease of use, as shown in Figure 1 below.

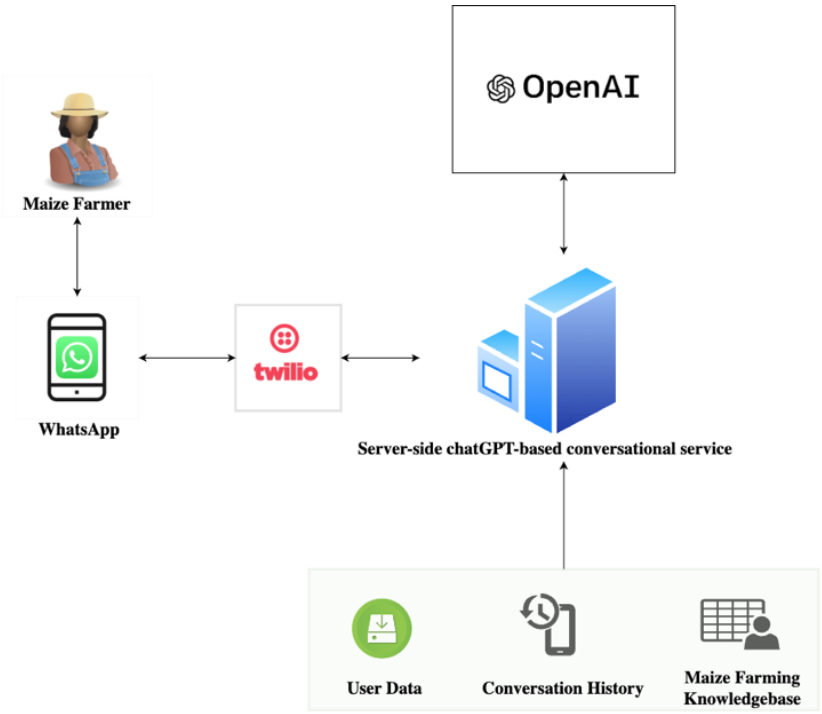

Figure. 1. MkulimaGPT Development Architecture

OpenAI GPT Model

MkulimaGPT has been developed by utilizing the OpenAI GPT-3.5 turbo model with advanced natural language processing capabilities to process more than 4096 tokens. This is one of the large language model types that can contextualize and understand language. The model has been trained to comprehend and converse in Swahili, ensuring linguistic precision and cultural resonance (OpenAI API, 2023).

Additionally, this large language model (LLM) uses artificial neural networks and is pre-trained using self-supervised and semi-supervised learning. This pre-training encompasses a vast expanse of language contexts, enabling the model to generate responses that are not only grammatically correct but also contextually aware.

This technological advancement is especially impactful for farmers, as personalized interactions are crucial in their line of work. It has been reported that LLM-powered chatbots

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are able to efficiently handle complex queries and provide detailed, precise solutions, leading to improved user satisfaction. This ability to engage in intricate conversations and offer comprehensive explanations highlights the potential of LLMs to revolutionize the way chatbots interact with users, ensuring that responses are not only relevant but also empathetic and supportive (Lund et al., 2023). Moreover, this autoregressive nature of these language models powers MkulimaGPT, as they predict the sequence of words that should logically follow any given text input. Hence, this capability makes the GPT-3.5 model suitable and exceptional for chatbot development, as it aligns with MkulimaGPT's mission to provide conversational assistance that feels as natural and intuitive as speaking to a knowledgeable local expert.

Twillio API

MkulimaGPT frontend technology utilises the Twilio API to seamlessly integrate web technologies with WhatsApp, enabling robust conversational messaging capabilities. This API serves as a versatile communication conduit, supporting both text and media exchanges between the user and the bot. Additionally, Twilio API has demonstrated great potential in enhancing conversational chatbots and real-time messaging applications. By integrating Twilio's robust communication APIs, sophisticated chatbots can seamlessly handle SMS, voice, and WhatsApp interactions. This capability enables real-time, personalized communication that enhances user satisfaction. Twilio's API supports the development of chatbots that can manage complex customer queries and automate responses, which is particularly valuable in agriculture, where immediate and accurate responses are crucial for managing crops (Twilio, 2023). Users can interact with MkulimaGPT via text or voice media, such as voice notes, facilitating questions and answers in various formats as needed. The integration of Twilio's WhatsApp API is a pivotal aspect of MkulimaGPT's development, ensuring interoperability and providing farmers with direct access to dialogues with the chatbot from their WhatsApp accounts, enhancing the user experience with seamless, frictionless communication.

Maize Farming Knowledgebase

MkulimaGPT initiative is centered on a carefully curated knowledge base exclusively dedicated to maize cultivation in Tanzania. The knowledge base was implemented in this work because integrating a custom knowledge base into conversational chatbots can significantly enhance their context and cultural relevance, making them more effective and personalized. By incorporating domain-specific knowledge, chatbots can offer more accurate and contextually appropriate responses (Owczarek, 2024). A study by (Lin et al., 2023) describes an effective method for integrating a custom knowledge base using vector databases and embedding models. These technologies enable the chatbot to conduct similarity searches within a custom knowledge base, retrieving the most relevant information to include in responses. This approach leverages in-context learning, allowing the chatbot to adapt its responses based on the specific context provided by the custom knowledge base, ensuring the delivery of specialized and relevant information efficiently.

This knowledge base is continuously updated with the latest agricultural practices, research breakthroughs, and localized farming advisories, making it a vital resource for MkulimaGPT to offer precise and practical advice. The depth of this knowledge base is derived from an extensive study conducted in the maize-producing districts of Mvomero and Gairo in Tanzania's Morogoro Region. These districts were selected for their prominent role in national maize output, as noted by (Morogoro et al., 2015). The study involved surveying farmers and

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extension officers with a set of 178 relevant questions about maize farming, as sampled in Table 1 below, which were designed to capture the unique agricultural environment of the region. Besides that, the study gathered insights from maize farmers in the Gairo and Mvomero districts of Tanzania using a cross-sectional approach. The study involved 300 participants, 150 from each district. The research focused on the farming community's expertise in maize agriculture. The snowball sampling technique was used to ensure that the respondents had enough knowledge about maize agriculture. The data collected was analyzed through Inter-rater reliability analysis to ensure data integrity and relevance. This analysis focused on the consistency of information related to various maize farming topics, including soil preparation and post-harvest management. The resulting dataset has helped to enhance the chatbot's capacity to provide reliable guidance to farmers. The chatbot utilizes authentic and field-tested data to provide contextually rich and relevant advice to farmers.

Table 1: Questions and Answer Sample in English and Swahili Language

Maswali (Swahili)	**Questions**	**Majibu (Swahili)**	**Answers**
Jinsi gani upepo unavyosababisha mmomonyoko wa udongo unathiri mimea ya mahindi katika bustani? yangu?	How does wind cause soil erosion and affect corn plants in my garden?	Upepo huondoa safu ya juu ya udongo na kupelekea kuathiri mizizi ya mimea ya mahindi hiyo kupelekea mmea kushindwa kukua vyema kwa kukosa virutubisho vinavyokuwa kwenye safu ya juu ya udongo lakini pia kushindwa kuwa imara kwani sehemu ya mizizi hukosa sehemu ya kushikiria hali inayopelekea mimea kuwa dhoofu na kuanguka.	Wind removes the top layer of soil and affects the roots of corn plants, causing the plant to be unable to grow well due to lack of nutrients in the top layer of soil, but also unable to be stable because the root part lacks a place to hold on, which leads to plants becoming weak and falling.
Umuhimu wa uchavushaji kwa mmea wa mahindi ni upi?	What is the importance of pollination for corn plants?	Uchavushaji husaidia mmea kuweza kuzalisha tunda. Urutubishaji wa mbegu za kike katika unaofanywa na mbegu za kiume (mbelewele) husabaisha kuzaliwa kwa ua ambalo ni tunda la mhindi>	Pollination helps the plant to produce fruit. Fertilization of the female seeds by the male seeds (pollen) causes the birth of a flower that is the fruit of corn.
Yapi kati ya Mahindi yaliyokauka na mahindi mabichi, nhuwa na faida ya kipato zaidi?	What are the differences between dried and fresh corn, and what are the income benefits?	Bei ya mahindi mabichi au makavu hutegemea soko husika na mahitaji. Mahindi mabichi huuzwa kama mhindi mmoja mmoja, mahindi makavu hununuliwa baada ya kuwa yamepukuchuliwa, kukobolewa au kusagwa kwa ajili ya kutengeneza unga wa chakula.	The price of fresh or dry corn depends on the relevant market and demand. Fresh corn is sold as individual corn, while dry corn is bought after being husked, milled, or ground for making flour.

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Mmea wa mahindi una aina gani ya mizizi?	What type of root system does a corn plant have?	Mmea wa mahindi huwa na aina ya mizizi miemabamba kama nyuzi , inayogawanyika kwa wastani ikikua kutoka kwenye shina. Aina hii hupatikana kwa mimea ya monokotiledoni na huonekana kama mkeka uliojengwa kwa mizizi pindi mmea unapofikia ukomavu kamili	Corn plants have a type of thin, fibrous roots, which are moderately branched, growing from the stem. This type is found in monocotyledonous plants and appears as a mat made of roots when the plant reaches full maturity.

RESULTS AND DISCUSSION

User Interactions and Bot Responsiveness

MkulimaGPT enabled users to ask questions and obtain answers from the chatbot developed via WhatsApp using a given mobile phone number; Figure 2 shows questions asked by a user and responses given by the MkulimaGPT chatbot through texts and voice notes.

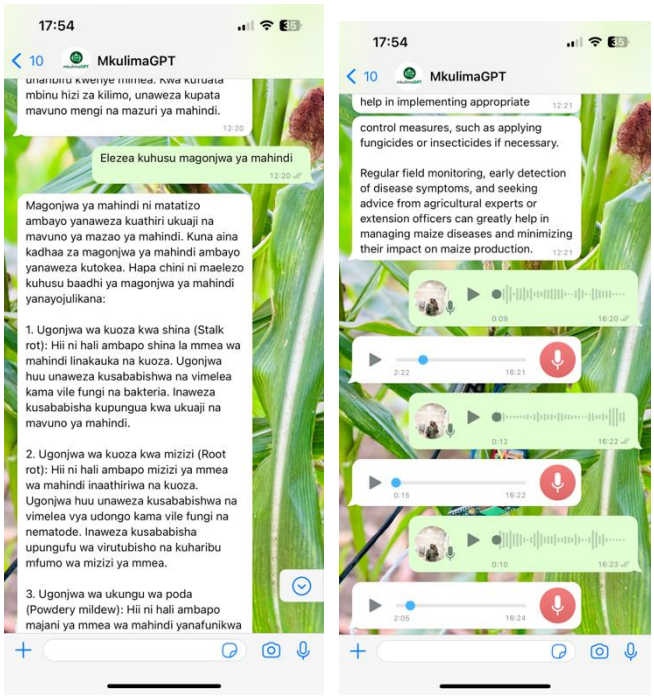

Figure 2. MkulimaGPT Questions and Answers

The effectiveness of MkulimaGPT in providing advisory information to farmers was rigorously analyzed by studying the chatbot's interactions for three months. We collected a wide range of data from these interactions, primarily consisting of question-and-answer exchanges done via the WhatsApp platform. This included textual and voice note formats and took place in various settings, from group interactions to one-on-one dialogues.

Throughout this user interaction analysis phase, 78 users actively engaged with MkulimaGPT, leading to a rich dataset comprising 1,028 instances of inquiries and responses, with 51 of these

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conducted through voice notes, as shown in Figure 3. Moreover, (Chen et al., 2021) argue that responsiveness and usability metrics are often assessed using different sample sizes. A sample size of 78 users with 1000 interactions provides a substantial dataset for analysing patterns and drawing meaningful conclusions about the chatbot's performance. This sample size allows for the identification of trends and potential areas for improvement, ensuring that the chatbot can effectively handle real-world usage scenarios. Leveraging a sample size of 78 users and 1000 responses is adequate to categorize a chatbot as responsive and useful, especially when supported by structured evaluation methodologies and empirical findings from related research. This approach ensures a reliable assessment of the chatbot's capabilities and user satisfaction.

This diverse collection of interactions allowed us to perform an in-depth evaluation of MkulimaGPT's performance. We specifically assessed the chatbot's accuracy, completeness, specificity, and language proficiency, ensuring a multifaceted understanding of its capability to manage and respond to a wide spectrum of user inputs, as shown in Figure 4.

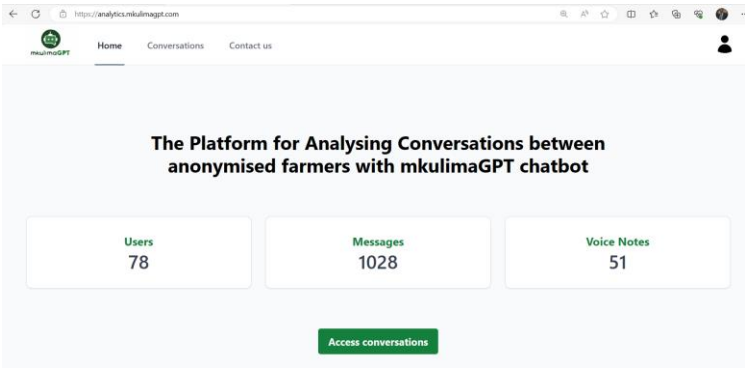

Figure. 3. Summary of the generated dataset from the interactive sections

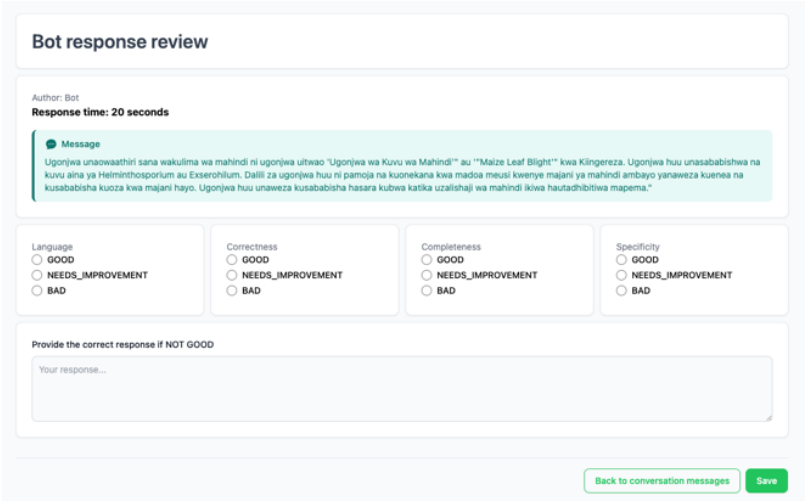

Figure. 4. MkulimaGPT Chatbot Review Parameters

Patterns in Questions and Response Quality

Examining the patterns of questions posed by users when assessing AI chatbots was an essential aspect for several reasons. Firstly, it helps in gaining a more comprehensive understanding of user needs and expectations, enabling us to tailor the chatbot's responses and

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functionalities accordingly. (Radziwill & Benton, 2017) indicates that such analysis can improve the chatbot's relevance and user satisfaction by ensuring effective addressing of the most common and critical queries. Additionally, this approach facilitates the identification of gaps in the chatbot's knowledge base and areas requiring improvement or additional training. Additionally, examining user question patterns provides valuable insights into the context and nuances of user interactions, which are vital for enhancing the chatbot's conversational abilities and contextual understanding. By categorizing and analyzing these interactions, we can optimize the chatbot's decision-making processes to ensure it delivers accurate, timely, and contextually appropriate responses.

During questions and response pattern analysis, it was noted that the most frequently asked questions focused on market availability because smallholder farmers depend on good markets to sell their crops at high prices to overcome food insecurity and increase income (Mutami, 2015). Additionally, the prevalence of maize diseases, a concern highlighted by (Misaki et al., 2016) prompted users to seek effective countermeasures, which underscores the importance of the chatbot's role in providing actionable agricultural advice. The chatbot's responses adhered to established criteria of completeness, correctness, and specificity. In light of the growing challenges posed by climate change, such as extended dry spells and unpredictable rainfall patterns, farmers sought guidance on optimal planting times. MkulimaGPT offered informed responses based on current climatic trends, albeit with some limitations in specificity due to ongoing environmental fluctuations. Furthermore, inquiries about seed selection were frequent, with farmers seeking varieties that promise high yields and are resilient to adverse weather and diseases—a concern echoed by (Gardezi et al., 2023). MkulimaGPT provided appropriate recommendations by identifying suitable seed types and compatible fertilizers, as shown in Figure 5, to support plant growth and maximize yield, as verified by agricultural experts who ensured that the advice given was both communicatively clear and agronomically sound.

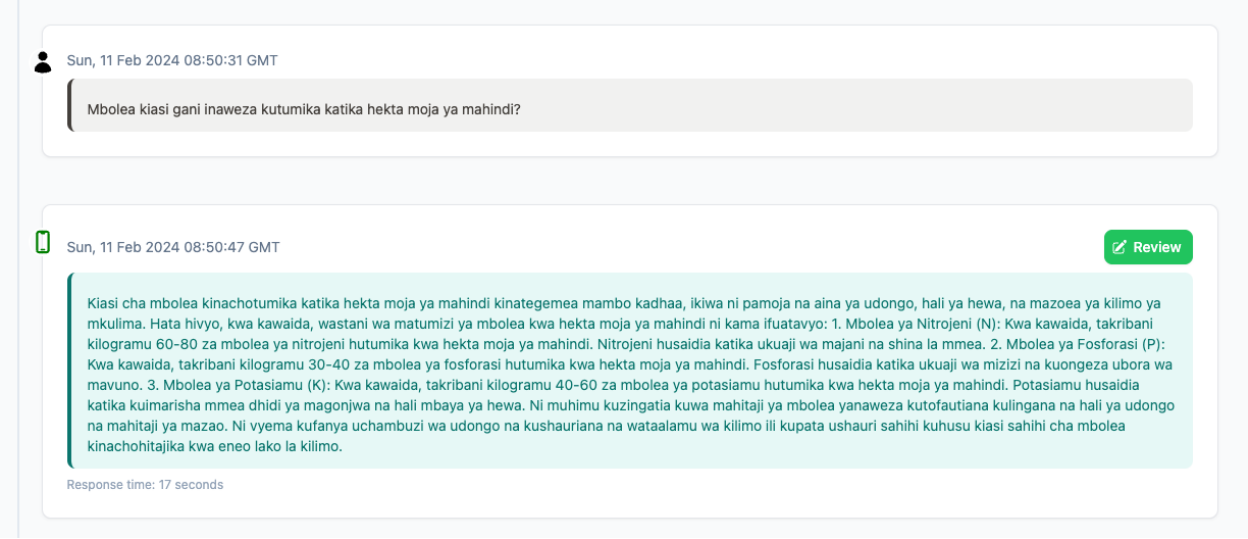

Figure. 5. Anonymized example of an exchange between a farmer and MkulimaGPT chatbot on fertilizer usage in Swahili

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Evaluation Criteria

In this section, we evaluated the obtained results and accuracy of the Chatbot system using multiple criteria. Due to the complex nature of chatbot development and implementation, the system requires various criteria to produce quality and usable results. One of the key factors when evaluating the effectiveness of most advanced chatbot technologies is their accuracy in terms of correctness, completeness, language precision, and specificity, as supported by (Hussain et al., 2019; Maroengsit et al., 2019) and as shown on Figure 6 and Figure 7. While evaluating MkulimaGPT chatbot responses, using identified metrics provided a structured framework for assessing the chatbot's performance and ensuring it effectively meets user expectations. Language evaluation was used to check that interactions were coherent and grammatically correct. Correctness was used to check that the information provided was accurate, preventing misinformation and building reliability. Completeness was used to check that responses were thorough, addressing all aspects of user queries to prevent frustration and follow-up questions. Time evaluation focused on response speed, critical for maintaining user engagement and providing a smooth experience. Lastly, specificity was used to check if responses were tailored and relevant to the user's specific needs, improving the overall utility of the chatbot (Caldarini et al., 2022).

48	16	4	2	62	1	5	2	61	3	4	2	9	9	50	2	60	4	4	2
69%	23%	6%	3%	89%	1%	7%	3%	87%	4%	6%	3%	13%	13%	71%	3%	86%	6%	6%	3%
Good	Needs improvement	Bad	No response	Good	Needs improvement	Bad	No response	Good	Needs improvement	Bad	No response	Good	Needs improvement	Bad	No response	Good	Needs improvement	Bad	No response
Language				**Correctness**				**Completeness**				**Time**				**Specificity**			

Figure. 6. General Reviews on Sampled responses from MkulimaGPT chatbot

Correctness: Ensuring correctness is paramount as it evaluates the chatbot's response to match the user's query. To establish the reliability and precision of the chatbot's information, each response was rigorously reviewed by a team of agricultural experts. These experts compared MkulimaGPT's answers to established agronomic knowledge and best practices in the field. Through this expert evaluation, 86% of the responses were deemed to exhibit a high degree of accuracy, which suggests that MkulimaGPT has the potential to provide precise information.

Completeness: The main objective of evaluating completeness was to ensure that the chatbot's response covers all aspects of the query; 87% showed that the MkulimaGPT chatbot gave complete responses as expected by users. This was done to equip the user with all the necessary information to meet their needs.

Language Precision: Assessing language accuracy when evaluating coherent and understandable conversations was critical for this task, and 69% of the returned responses had proper language detection and understanding to users. The assessment covered the aspects of syntax reviewing, vocabulary, and grammar because there are instances when chatbot responses are grammatically incorrect or use confusing language, which can lead to misunderstandings for the user.

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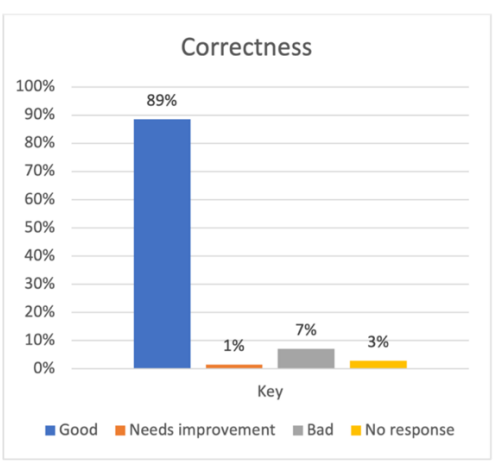
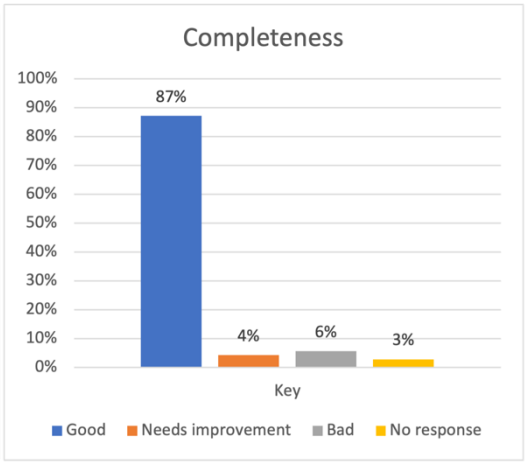
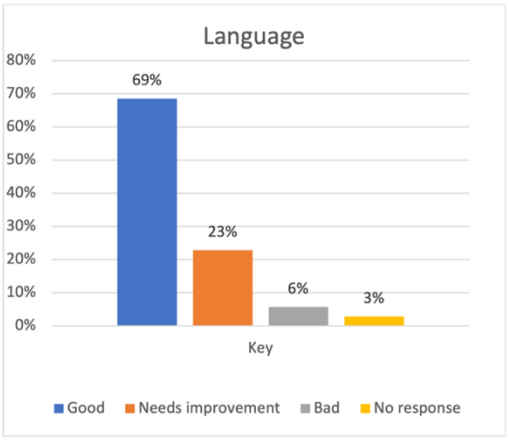
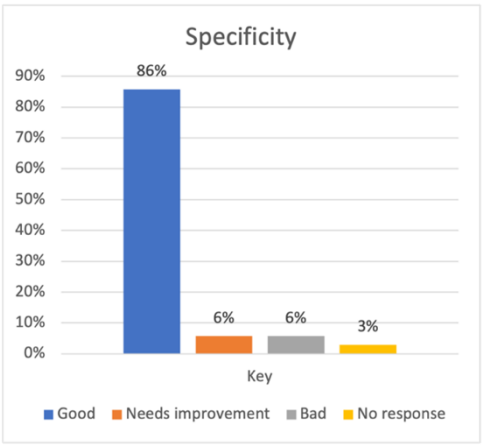
Specificity: In this context, a specific response always provides more value to the user by directly addressing their queries and providing relevant information. 86% of responses had specific answers to questions asked by users, contributing to the chatbot's ability to meet the user's needs.

Time: An additional metric considered in the evaluation of MkulimaGPT was the response time. The upgrade to the more advanced GPT-4 model during the review period initially resulted in longer response times. While 71% of the responses were categorized as 'bad' due to exceeding the 20-minute threshold, this was largely attributed to the integration phase of the new AI model. The extended response times were a temporary consequence of adopting cutting-edge technology designed to enhance the chatbot's contextual understanding. While the Time metric initially suggests an area for improvement, it also highlights the dynamic nature of AI development and the inherent trade-offs when implementing upgrades to achieve superior service in the long run.









Article DOI: 10.52589/AJAFS-VERNTB5I
DOI URL: https://doi.org/10.52589/AJAFS-VERNTB5I

African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 4, 2024 (pp. 172-188)

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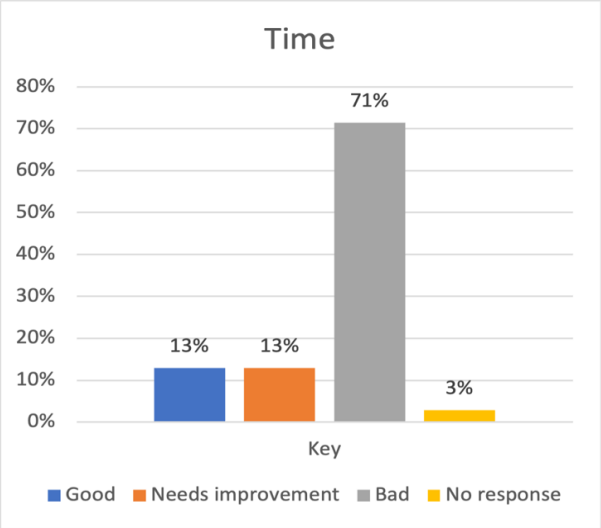

Figure. 7. MkulimaGPT reviewed response scores.

IMPLICATION TOWARDS DECISION-MAKING

The MkulimaGPT Swahili Chatbot has the potential to assist Tanzanian smallholder farmers significantly by supporting their decision-making processes for day-to-day maize farming activities and enhancing their agricultural knowledge. The chatbot has played a pivotal role by providing AI-driven responses for informed maize crop management. The responses' accuracy and specificity, as validated by agricultural experts, ensure that the information disseminated is both relevant and reliable—factors essential for effective agricultural practices. Research suggests that the precision of AI-driven responses is critical for impactful decision-making across various fields, including healthcare and agriculture (Al-Ashwal et al., 2023). MkulimaGPT demonstrates this capability by delivering responses in Swahili that reflect an understanding of the local agricultural context, which is instrumental in improving the knowledge base of farmers. This understanding, rooted in the cultural nuances specific to Tanzanian society, is vital for encouraging the adoption of new technologies (Petrović & Jovanović, 2021).

The chatbot's ability to provide accurate and comprehensive responses has been instrumental in fostering user satisfaction and trust—a fundamental aspect of technology acceptance in the agricultural sector, where conventional practices are prevalent (Raj et al., 2023). As compared to other research, a study by (Rao et al., 2023), ChatGPT achieved an overall accuracy of 71.7% across 36 clinical vignettes, covering tasks such as differential diagnosis, diagnostic testing, and care management. The chatbot's performance was on par with that of medical school graduates, suggesting its potential to support healthcare professionals in making well-informed decisions. This level of accuracy is crucial as it ensures that patients receive appropriate and timely medical advice, ultimately improving outcomes and efficiency in clinical settings.

Performance Strengths and Opportunities for Improvement

Recognizing the performance strengths of a chatbot is essential for understanding its areas of excellence and ensuring that it continues to meet user expectations and provide high-quality service. Factors such as the quality of provided information, system reliability, and adaptability

Article DOI: 10.52589/AJAFS-VERNTB5I
DOI URL: https://doi.org/10.52589/AJAFS-VERNTB5I

significantly influence customer satisfaction and engagement. Upholding and expanding on these strengths is crucial for building trust and reliability among users. Additionally, identifying areas for improvement is vital for the ongoing advancement of chatbot technology. This includes recognizing areas where the chatbot may have shortcomings, such as handling specific types of queries or maintaining context during lengthy interactions. (Gökçearslan et al., 2024) emphasizes that continuously evaluating and enhancing the chatbot based on user feedback and performance metrics is key to creating a responsive and effective chatbot.

Assessment of MkulimaGPT revealed areas of excellence and potential enhancement, particularly in catering to users with varying literacy levels. The chatbot displayed a commendable accuracy rate in providing correct responses to user inquiries, exhibiting reliability in information dissemination. Particularly noteworthy was the chatbot's voice interaction feature, which proved to be highly beneficial for users with limited reading skills. Our analysis, mirroring findings from similar studies (Jain et al., 2018), indicated that audio inputs were especially valuable for semi-literate users by providing a more accessible and straightforward means of communication. Despite this, both voice and text interactions occasionally resulted in misunderstandings or incorrect responses, highlighting areas for improvement in the system's processing capabilities. To address these challenges, we are considering several upgrades, including the enhancement of the audio interface to improve the accuracy and speed of responses. While text interactions have the added benefit of supporting incidental learning of language and are preferred by some to avoid the stigma associated with illiteracy, optimizing the chatbot for voice interactions remains a priority. Future enhancements will focus on refining MkulimaGPT's interpretation algorithms through advanced machine-learning techniques, aiming to boost overall response quality and efficiency in handling voice queries.

CONCLUSION

MkulimaGPT Swahili Chatbot has been designed as an AI solution to help maize farmers in Tanzania. It has been created specifically to tackle the unique challenges these farmers face. The chatbot is crafted to provide information and advice to help improve the farming process. It is easy to use and provides clear instructions. By using the chatbot, maize farmers can benefit from a more efficient and productive farming experience. Furthermore, the interface goes beyond the limitations of traditional chatbots by utilizing the advanced natural language processing capabilities of OpenAI's GPT-3.5 turbo model, providing a contextually intelligent language interface for WhatsApp users.

To top the technological aspect, the data approach of the knowledgebase is rooted in empirical research conducted in Tanzania's maize-rich districts, which reflects the collective contexts and practices of the local farming community, ensuring that the chatbot's guidance is accurate and steeped in its user's lived experience. This responsiveness to local needs is further enhanced by the platform's learning algorithms, which adapt and personalize interactions using farmers' data and conversation history, fostering an increasingly tailored user experience. Looking to the future, MkulimaGPT is expected to be incorporated with IoT sensor data and real-time analytics to elevate the smart farming ecosystem. As it stands, MkulimaGPT is not merely a technological venture; it is a catalyst for agricultural empowerment and a testament to the transformative potential of context-aware AI applications in resource-constrained environments. Its development methodology and deployment serve as a replicable blueprint

Article DOI: 10.52589/AJAFS-VERNTB5I
DOI URL: https://doi.org/10.52589/AJAFS-VERNTB5I

for similar initiatives globally, paving the way for a future where AI-driven agricultural advisories can flourish, tailored to the needs and languages of farmers worldwide.

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