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**The use of artificial intelligence-based innovations in the health sector in Tanzania: A scoping review**

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**Authors' contributions:** FS, and DS were responsible for the concept and design. FS, DM, RB and DS did the study selection. FS, RB, DM and DS did the data extraction, critical appraisal, and coding. FS and DM drafted the manuscript. All authors critically revised the manuscript for intellectually important content and verified the underlying data.

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Not applicable.

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Not applicable.

**Running title**

Artificial intelligence in Tanzania

**Highlights**

- 18 publications related to AI applications in the health sector in Tanzania
- There are no national policies, regulations and guidelines for the adoption of AI
- Rising interest in the adoption of these emerging technologies in health services
- Technical, organisational, data and individual-related challenges hinder AI-driven innovations



**Abstract**

**Background:** Artificial Intelligence (AI) has great potential to transform health systems to improve the quality of healthcare services. However, AI is still new in Tanzania, and there is limited knowledge about the application of AI technology in the Tanzanian health sector.

**Objectives:** This study aims to explore the current status, challenges and opportunities for AI application in the health system in Tanzania.

**Methods:** A scoping review was conducted using the Preferred Reporting Items for Systematic Review and Meta-Analysis Extensions for Scoping Review (PRISMA-ScR). We searched different electronic databases such as PubMed, Embase, African Journal Online and Google Scholar.

**Results:** Eighteen (18) studies met the inclusion criteria out of 2,017 studies from different electronic databases and known AI-related project websites. Among AI-driven solutions, the studies mostly used machine learning (ML) and deep learning for various purposes, including prediction and diagnosis of diseases and vaccine stock optimisation. The most commonly used algorithms were conventional machine learning, including Random Forest and Neural network, Naive Bayes K-Nearest Neighbour and Logistic regression.

**Conclusions:** This review shows that AI-based innovations may have a role in improving health service delivery, including early outbreak prediction and detection, disease diagnosis and treatment, and efficient management of healthcare resources in Tanzania. Our results indicate the need for developing national AI policies and regulatory frameworks for adopting responsible AI solutions in the health sector following the WHO guidance on ethics and governance of AI for health.

**Keywords:** Artificial intelligence, machine learning, deep learning, neural network, health sector, Tanzania

**BACKGROUND**

Delivery of health care services is evolving with rapid technologic development. Artificial intelligence (AI)-based innovations, in particular, have increasingly demonstrated great potential for transforming and disrupting the provision of healthcare services in both high-income countries (HICs) and low and middle-income countries (LMICs) [1]. Machine learning-based AI technology offers a unique opportunity for automated analysis of the available massive health-related data generated from the health system. Although AI technology has been around since the 1950s, the technology has recently attracted particular attention in research and industry communities due to the rise of computational power [2, 3].

AI systems are partially or wholly autonomous machine-based systems that can use statistical and mathematical modelling techniques for a given set of human-defined objectives and make predictions, recommendations, or decisions influencing real or virtual environments [4]. AI-based health and welfare technologies are rapidly being used in health care for screening and early detection devices and applications, health tracking applications, and treatment with precision.

Emerging evidence indicates that machine learning-based AI applications improve the efficiency of integrated public health disease surveillance and response systems [5]. People with chronic diseases can be monitored using smart devices, for instance, sensors and wearable textiles, thus improving the patientôs health and well-being and communication between patients, caregivers and healthcare workers [1]. The medical AI technology can be applied in facility and home-based care, even in resource-constrained and rural settings [6, 7]. Analytics and reasoning capabilities of the AI technology can be implemented in or using the existing patient information databases to support better decision-making with the potential to reduce chances of misdiagnosis, and mismanagement of health resources, enhance more individualised patient care and improve collaboration between healthcare workers and patients [8-10]. Similarly, embedded AI technology enhances device-level processesô automation, advanced business analytics and facilitation of patient-centred service delivery.

Furthermore, studies report that the COVID-19 pandemic has accelerated the adoption and use of AI in the health sector [11]. AI-related interventions have improved community health monitoring through smart sensors and analytics tools embedded in places such as workplaces and public places [12] and even in diagnosing COVID-19 using chest X-ray images [13].

In Europe, the health sector is one of the key areas in which AI can address numerous health system problems [14]. However, several challenges hinder the appropriate and effective application of medical AI. These challenges include privacy, cybersecurity, accuracy, intellectual property rights, accountability, transparency, explainability, performance, bias, and discrimination [14, 15]. It is therefore recommended that strategic decisions should be made when employing AI-based innovations to ensure that i) they are responsible, ii) the challenges are properly addressed, and iii) there is a balance between competing interests and values [14, 15]. Globally, there has been an increasing uptake of digital health initiatives during the COVID-19 pandemic, which may be sustainable after the COVID-19 pandemic. For instance, since January 2021, the European Commission has been supporting thirteen AI-related projects focusing on the detection and prevention of the spread of COVID-19 [12].

Although AI is the driving force of the fourth industrial revolution globally, most of the adoption, research and innovations have been happening in HICs. The technology has been well adopted in research and industry in North America and some European and Asian countries, while Africa has lagged. The Global AI index 2020 report provides the Government AI Readiness Index [16], and the lowest-scoring regions are sub-Saharan Africa (SSA), Latin America and the Caribbean, and South and Central Asia, with Tanzania ranking at 124 [16]. Health and technology experts and researchers from Africa need to actively participate in AI research, innovation and implementation to provide contextual and cultural perspectives. Thus, minimising potential unintended algorithmic biases and discriminations into AI products and services.

The health systems in Africa, especially SSA, including Tanzania, are challenged with many crises, such as poor health service planning and provision, limited human resources in the health sector and poor resource management as well as inadequate visibility and use of quality data for informed decision making [17]. The AI applications offer great potential to transform or disrupt the provision of healthcare services, including promotive, preventive, curative and rehabilitative healthcare interventions. This situation calls for governments and stakeholders to devise appropriate strategies for a well-informed AI-based technological adoption to maximise the benefits of and minimise disruptions from these emerging technologies. Although many SSA countries do not yet have clear guidelines and policies on the development and use of AI-driven solutions, they can adopt recently released WHO guidelines on ethics and governance of AI for health [18].

Like other countries, the United Republic of Tanzania is committed to addressing health system challenges with emerging technologies such as AI-based innovations. Tanzania, the largest country in the East African Community, covers an area of 947,300 square kilometres. Tanzania has an estimated population of 61.7 million in 2022, divided into 31 regions and 197 districts. Over 31 million people in the country use the internet. Tanzania's health system is organised in a pyramidal structure, beginning with the community and progressing to the national level. The health system in Tanzania Mainland has over 8000 health facilities, and Zanzibar, a semiautonomous region, has about 300 health facilities offering a wide range of healthcare services.

The Tanzanian health sector faces many challenges [19] and can benefit from AI-driven interventions. However, there is limited knowledge of the application of AI-based innovations in the Tanzanian health system. Therefore, this study aimed to explore the current status, challenges and opportunities for applying AI-based innovations to address the health system challenges in Tanzania.

## METHODS

### Study design and setting

This scoping review of studies that focused on the applications of AI-based innovations in the health sector in Tanzania is reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Extensions for Scoping Review (PRISMA-ScR) [20, 21].

### Eligibility criteria and search sources

The search included topics on the current status, challenges, and opportunities of using AI in the Tanzanian health system. We searched electronic databases such as Medline/PubMed, Embase and Google Scholar. We also retrieved relevant references from other suitable websites. Search terms such as deep learning, machine learning, neural networks, artificial intelligence, artificial intelligence-based assessment, AI, health sector, Zanzibar and Tanzania were used to construct a search log for retrieving relevant literature. We also used the medical subject headings for key terms to retrieve the most similar articles. All study designs were considered for inclusion. There was no restriction on publication type and date. Articles were excluded if they were not published in the English language.

A search of three electronic databases and five relevant institutional websites related to AI was conducted to identify publications for this scoping review study. An initial search was conducted on August 3, 2021, using three different electronic databases: PubMed/Medline, Google Scholar, and Embase. The same search was manually performed on November 31, 2021 on five institution/project websites. On July 19, 2022, a new search was conducted on the three electronic databases and the five institutional websites to find any additional literature published since the initial search. The search strategy used for the scoping review in PubMed, Embase and Google Scholar and the websites included is presented in Appendix I.

### Selection of sources and data charting process

The results of all searches were integrated into Covidence systematic review management software [22], and duplicates were removed. The screening for article inclusion took place in two phases facilitated by the Covidence software. First, the title and abstract of all searched articles were screened independently by two reviewers and categorised as ñNoò if both of the reviewers recommended the paper to be rejected, ñMaybeò if one of the reviewers or both were uncertain, then the third part would intervene to solve the contradiction and ñYesò if both of the reviewers recommend the paper to be approved to be used in the review. Secondly, the full text of all articles was reviewed by two independent reviewers in the same manner as the same phase regarding the final inclusion. No third reviewer was consulted to reach a consensus because there was no disagreement between the two primary reviewers.

We developed a Microsoft Excel file for data charting to ensure that relevant and consistent information is captured. The selected articles were charted to the comprehensive data extraction table to record all findings with a potential value to this scoping review. The thematic analysis was undertaken to synthesise the extracted data, resulting in five key themes: study characteristics, study methods, AI status, AI implementation challenges, and opportunities for AI implementation. Thematic analysis, a crucial technique for qualitative research, allowed us a flexible approach to producing a rich, detailed interpretation of the articles included. We used the 6-phase process proposed by Boyatzis and used by Braun and Clarke [23, 24]. It has been suggested that this method could be used instead of weighting individual articles based on their contributions to provide a more thorough account of the topic. Two reviewers (the first and the second authors) independently reread the articles and developed initial codes for each, extracting representative text to support the coding. We then reviewed all the codes as a group and agreed on the differences to create a single, definitive set of codes. We have compiled these codes to develop applicable issues and identify relevant ones.



## RESULTS

### Selection of sources of evidence

A total of 2,017 records were retrieved, whereas 18 articles met the inclusion criteria for the scoping review, as shown in the PRISMA-Scoping Review diagram in Figure 1.

### Characteristics of the studies included this review

A total of 18 studies were included, in which 13 published articles were from peer-reviewed journals, and 5 were grey literature from known AI-related project websites. The studies explored different applications of AI in healthcare, including prediction of the cholera outbreak, prevention of perinatal death, prediction of neonates with low Apgar scores after induction of labour, maintenance of optimal vaccine stocks, diagnosis and treatment of malaria, and case management and pay for performance (Table 1 and Table 2).

The reviewed studies indicate that machine learning-driven solutions can be used to optimise health resources and efficiency in the Tanzanian health sector. Examples are demonstrated below.

Leo and colleagues [25] used a machine learning (ML) model to predict cholera epidemic outbreaks based on seasonal weather changes while overcoming the data imbalance problem. This is an AI-based innovation in data analysis and decision-making on cholera in Tanzania. The study improved understanding of how numerous ML strategies can be used in health data and recommended a review of existing health information systems to enhance quality in data collection and management as well as applications of ML techniques.

Another AI technology has been applied in the diagnosis and treatment of malaria [26]. It was demonstrated that mid-infrared (MIR) spectroscopy coupled with a supervised ML (i.e. MIR-ML) model could be used to rapidly screen for malaria parasites in dried human blood spots. This approach has a potential for rapid and fast data throughput malarial screening as the MIR-ML spectroscopy system is physically robust and low-cost regarding minimum maintenance.

ML models were used to determine the critical predictors of perinatal deaths in a birth registry cohort [27] and establish the most efficient boosting method in predicting neonatal low Apgar scores following labor induction interventions among pregnant women at a tertiary hospital [28].

In a study by Silver et al. [28], an ML model was used for forecasting vaccine utilization in Tanzania using the vaccine utilisation data from health facilities. The model accurately predicted vaccine utilisation at the individual health facility level.

Bezu et al. [29] examined the impact of a payment-for-performance (P4P) scheme on reducing the incidence of pregnant women bypassing nearby health facilities for delivery services in facilities with better equipment and more qualified staff. An ML approach was used to identify factors that predicted bypassing health facilities, and it found that women are less likely to bypass if residing close to a hospital and their local facility is a hospital or a health centre rather than a dispensary [29].

Milali et al. [30] developed an autoencoder and artificial neural network-based methods to estimate the parity status of wild mosquitoes from near-infrared spectra as an alternative tool to estimate the parity status of wild mosquitoes.

The study by Lucy [31] used different algorithms to predict the stunting status among children under five years of age, which will help the design and implement interventions for addressing malnutrition in those under-five.

The searches of the grey literature from Google Search show the implementation reports of AI-related applications, including in health supply chain management. The report shows how the Government of Tanzania can begin implementing AI-driven solutions for health supply chains in Tanzania. For instance, there is an ongoing pilot Elsa Health, from Elsa Health Company which is developing AI-powered clinical decision support algorithms for healthcare providers to improve diagnostics using AI-powered decision support tools for primary care providers [32].

A survey conducted in Tanzania, which explored the perceptions of stakeholders on the use of AI for health supply chains in Tanzania, shows that over 60% of respondents agreed that Tanzania is ready to implement AI due to the effort made by the Government of Tanzania and its stakeholders in investing in an integrated and electronic data storage such as the Vaccine Information Management System (VIMS), Tanzania Immunization Registry (TImR), electronic Logistic Management Information System (eLMIS) and District Health Information System (DHIS2) that provide high-quality routine health data [33].

Another study conducted to understand the extent of misleading information related to COVID-19 by using web scrapping on Twitter data demonstrated how the AI-based application can automate the analysis of social media data [34].

Another grey literature report demonstrated the potential of AI-driven solutions to increase efficiency in the Tanzanian health sector [32]. For example, the AI product of Macro-Eyes Health, a vendor of AI-powered supply chains, reduced vaccine stockouts and wastage and provided forecast vaccine uptake with greater accuracy, thus improving vaccine delivery and patient scheduling. Another example is Ada Health, the worldôs first AI health guidance app in Swahili, used to assist clinicians in early diagnosis or self-diagnosis of diseases [35], working closely with regional stakeholders to assist clinicians and patients in getting more information about potential symptomsô causes and recommendation for the next step.

In another study, researchers from Ifakara Health Institute used AI to accelerate malaria vector control and rapid assessment of blood-feeding histories and parasite infection rates in field-collected malaria mosquitoes [26]. Other examples of AI-driven solutions are provided by Jamii Africa, a start-up that provides health insurance for low-income populations using mobile phones [36].

Two more studies successfully utilised random forest algorithms in different cases in Tanzania. One study used the method to identify early biological measurements associated with preterm birth among pregnant women using transcriptomics and proteomics profiling of plasma and metabolomics analysis of urine [37]. Another study used the method to identify the most important predictors of sputum conversion, ADR, and death in Tanzanian patients with pulmonary multidrug-resistant tuberculosis treated with a levofloxacin-containing regimen [38]. Before the random forest method, the study [38] used two common unsupervised methods, the PCA and LDA, to create a 2-dimensional representation of the entire cohort used for the project, an important step in preparing data for supervised ML models.

**Challenges hindering the use of AI-based innovations in the health sector**

In this review, we also explored challenges reported by the selected publications and literature. Some of the challenges included limited access to or availability of large volume of high-quality data for training and validating and AI-based models, e.g. [37-39]. Some authors mention that common issues for machine learning algorithms include underfitting, overfitting, and data imbalances leading to biases or unfairness [32, 40]. Other challenges are data privacy and unethical use of the data and AI applications, lack of policy and strategy, and insufficient resources, such as human, infrastructure, and financial resources for the design, development, and implementation of AI-based solutions in the health sector [32, 41, 42].

## DISCUSSION

A scoping review of the current AI status and the challenges and opportunities of AI-based applications in the Tanzanian health sector was conducted. As far as we know, this is the first review focusing on AI-based innovations in the health sector in Tanzania. We found few publications on AI applications in the health sector in Tanzania due to several factors, including limited awareness of the available technologies [43]. However, given the nature of AI applications as one the emerging technologies, producing 18 publications from Tanzania on this new subject in just two years shows a growing interest in understanding and adopting these technologies to improve the quality of health services.

The review shows that AI-based innovations were applied in different use cases, such as the prediction and diagnosis of different diseases, e.g. prediction of cholera epidemics that may translate into the strengthening of disease surveillance and response systems, as well as the use of the ML algorithm for maintaining optimal vaccine stocks. From Table 1 above, it can be noticed that most of the studies applied AI in prediction (7 studies). For example, in one of the studies, regarding the ML model for imbalanced cholera datasets in Tanzania, authors applied ML-based AI in predicting cholera outbreaks by applying climate data. Another study on the use of AI to tackle the 'infodemic' in Tanzania applied social media data to track the status of COVID-19 and the spread of misinformation [34]. Future prediction using current data is highly significant, especially in resource-limited countries like Tanzania, as it will give room for early intervention. Although the early diagnosis of diseases can lower the burden of late-stage treatment of diseases and save more lives, and AI poses a potential tool for the diagnosis of diseases, only two studies were found to apply AI in the diagnosis of diseases in Tanzania, both for malaria [26, 39].

ML and deep learning as AI-based solutions rely on data for training models. Strong governance and ethics in obtaining, analysing, using and sharing the data and using the trained models are important elements towards implementing a responsible AI. While data is the lifeblood of AI applications, most healthcare organisations have plenty of data siloed within institutions. Such data can be used for AI applications, but the data has to be adequate with acceptable quality and formats that are fundamental for effectively exploiting complex, massive data [44, 45].

Furthermore, AI-based solutions, as well as other emerging technologies like drones, have great potential to address the challenges of healthcare systems in LMICs [46, 47]. This can be facilitated by harnessing the skills of the younger population, which is eager to learn and adopt these technologies while capitalising on an enabling environment of leadership and governance as well as the high penetration of mobile phones [46].

Implementing AI-driven solutions such as ML and deep learning models largely depends on the availability and quality of digital data for training the models. In LMICs like Tanzania, in which AI is still a relatively new concept [48], the health sector is faced with a myriad of challenges in adopting AI technologies [7, 49], such as the imbalance of datasets and missing information [25], as well as inaccurate and inconsistent data [50]. There is also the absence of ML or deep learning-ready datasets, as well as the existence of fragmented and parallel data systems that do not foster integration and/or interoperability [51].

Moreover, the grey literature shows the implementation of AI-based applications but the review indicates little application of deep learning in healthcare in Tanzania. Deep learning is a specialised subset of ML which uses a programmable neural network, thus enabling machines to make decisions accurately without human interventions. Through the use of deep learning in diagnosing and predicting diseases supported by clinicians, faster and more correct decisions can be reached than relying on human decisions alone [18]. The advantage of deep learning algorithms over conventional

ML is in avoiding manual feature extraction, which refers to the process of identifying and describing the features that are relevant to a given problem and implementing a way to extract those features. Manual feature extraction is a tiresome, complex, time-consuming process that leads to model overfitting and extracting unwanted or less important features.

The review further highlights several issues to be addressed, including strengthening the enabling environment for AI adoption in the healthcare sector. It recommends the development of foundations such as required digital infrastructure, legal and regulatory framework, capacity building initiatives, mapping AI initiatives and actors and instituting mechanisms for fostering collaboration and partnership among local, national and international stakeholders. This will align with the recent WHO guidance on ethics and governance of AI for health [18]. The guideline emphasises the need to ensure that AI-related applications are responsive and responsible for the needs of all stakeholders. The AI applications should be effective and efficient for healthcare workers while ensuring that it is accountable and responsible to the communities and individuals whose health will be affected by their use.

It is critical to implement appropriate, affordable, and user-centred digital solutions and services, including responsible AI-driven solutions across the health sector to facilitate the attainment of various national health goals. Despite its proven capability to resolve critical health sector challenges, several factors hinder the implementation and operability of AI-based technologies in the Tanzania healthcare system. This review presents five factors which are: inadequate modern computing infrastructure, limited awareness among stakeholders, limited skills in AI solution development, lack of policy and regulatory framework around the technology, and limited availability, quantity and quality of datasets. These circumstances indicate the need for capacity-building initiatives in using AI-driven applications and services among system developers, health professionals, researchers, policy and decision-makers in Tanzania.

Moreover, there is a need to design appropriate interventions for tackling some of the potential social and ethical issues around the use of AI-based technologies, such as the collection and use of personal health data for AI-based decisions, including data privacy and the collection and use of personal health data for AI-based decisions. Opening personal health data could lead to mismanagement and misuse [36, 40-42]. Thus, addressing the big data-related limitations will improve the validity, specificity, and sensitivity of the AI-based algorithms to make results more valid and responsible.

Therefore, it is paramount to strengthen an enabling environment, including policy and regulatory framework, supportive computing infrastructure and skills among different stakeholders. The World

Health Organisation (WHO) has recently developed policies and principles to inform the Member States on the ethics, governance and responsible application of artificial intelligence for health [18]. In addition, the WHOôs 2020-2025 Global Strategy on Digital Health recognises the role of emerging technologies, including AI, in ensuring that 1 billion more people benefit from universal health coverage while many countries still need institutional support to leverage emerging technologies to achieve the vision of health for all [42].

**Policy and practice implications**

The study findings may be helpful for policy- and decision-makers, researchers, practitioners and other stakeholders interested in leveraging digital health technologies, particularly AI, towards improved quality of public health services and health system performance. In this context, we suggest the development of national AI policies and regulatory frameworks for responsible AI-driven solutions in the health sector. Based on our results, Tanzania has a great potential to set up the best example for other countries in the Sub-Saharan Africa of how such policies and frameworks can be adapted at the national level.

The national policies would facilitate an informed adoption and uptake of AI-related solutions in the country through standardisation and transformation of data governance and sharing, raising awareness and building the capacity of the government and health sector stakeholders. The proposed regulatory framework is expected to be aligned with the WHO guidance on ethics and governance of AI for health [18], which emphasises the following guiding principles include: i) protect autonomy; ii) promote human well-being, human safety, and public interest; iii) ensure transparency, explainability, and intelligibility; iv) foster responsibility and accountability; v) ensure inclusiveness and equity; and vi) be responsive and sustainable. These guidelines address the recent discussion of AIôs bias and other challenges to its use in health applications.



**Strengths and Limitations**

As far as we know, this is the first review that broadly assesses AI-based innovation in the health sector in Tanzania. This review can potentially contribute to building research capacity in the AI-driven delivery of healthcare services and the development of future AI-based innovations.

In this review, our search for publications included all possible terms related to the use of AI, machine learning, and deep learning models or solutions in the health sector. We searched in common electronic databases. Our review also included grey literature in which we retrieved publications describing ongoing research, innovation and application of AI in the Tanzanian health sector.

In this study, the review included only papers on AI applications in the health sector in Tanzania. Therefore, there could be publications on AI-related applications in other sectors. We might have missed studies that did not use the same or similar terms in their titles and abstracts. Also, the study was restricted to English papers only.

For a while, machine learning, especially deep learning algorithms, have been termed black boxes as it has been challenging to explain their decisions and their multilayer nonlinear structure [52]. Recently, there have been efforts to ensure these algorithms are explainable, which can be important elements for regulatory purposes. This also aligns with WHO guidelines for AI in healthcare which insist on transparency, explainability and intelligibility of AI solutions. Although AI research and applications are still in the early stages in Tanzania, two studies were found trying to implement the explainability functionality by looking into the factors contributing to their algorithmȏs decision [29, 43].

**Ethical considerations**

This study did not involve human participants or unpublished secondary data, and ethical approval for human research was not required.

**CONCLUSION**

A scoping review of 18 studies related to AI applications in the health sector in Tanzania shows rising interest in adopting these emerging technologies in health services but at a relatively low pace. The reviewed articles show challenges hindering AI-based technologies in the Tanzanian health sector, including poor data quality, limited AI-related skills and lack of standardisation in collecting data from specific areas. As the use of AI is new in Tanzania, there are no national policies, regulations and guidelines to guide the adoption and use of AI in addressing challenges faced by different sectors, including health. Results demonstrated in this paper can potentially support designing fit-for-purpose national policies and frameworks in countries with similar context as that of Tanzania, following the recent WHO AI guidelines. The ultimate goal would be to facilitate an informed adoption and uptake of sustainable, explainable and responsible AI-related solutions in the health sector. This would also align with the global initiatives on the strategic adoption and fast-tracking the uptake of emerging digital health technologies to combat global health challenges, including the COVID-19 pandemic [2].

**Abbreviations:**

AI: Artificial Intelligence; PRISMA-ScR: Preferred Reporting Items for Systematic Review and Meta-Analysis Extensions for Scoping Review; AJOL: African Journal Online.

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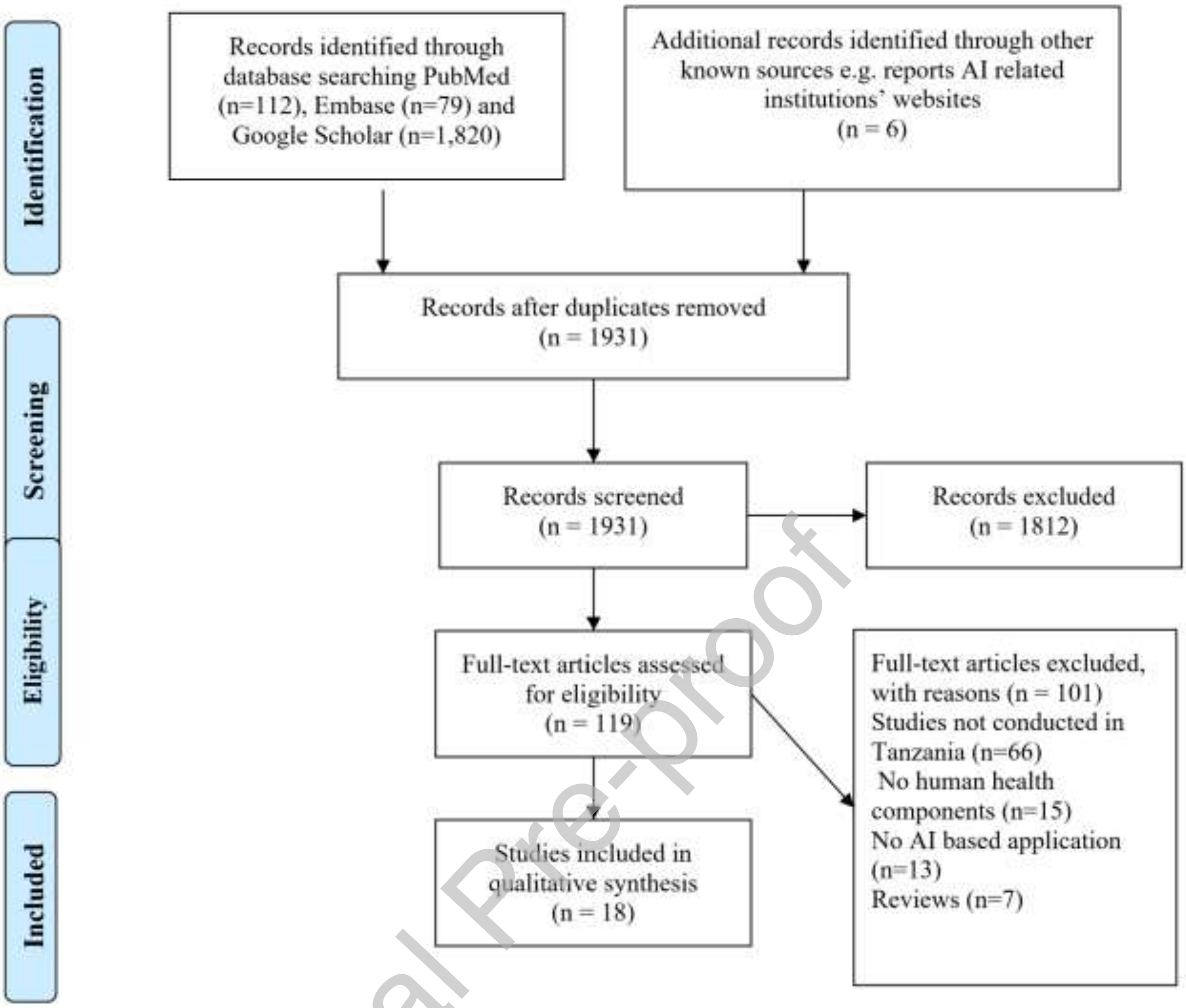


Figure 1: PRISMA- Scoping Review Flow Chart Diagram



**Table 1:** Features of publications on health AI-based innovations in Tanzania

| Serial No. | Author and year | Purpose and Area | Category | Algorithm used |
|---|---|---|---|---|
| 1. | Leo et al, 2019 [25] | Prediction of cholera outbreak using weather data | Conventional machine learning | XGBoost, K-Nearest Neighbors (KNN), Decision Tree, Random Forest (RF), Extra Tree, AdaBoost, and Linear Discriminant Analysis (LDA). |

| | | | | |
|---|---|---|---|---|
| 2. | Mwanga et al, 2019 [39]<br>10.1186/s12936-019-2982-9 | Detection of malaria parasites | Conventional machine learning | KNN, Logistic regression (LR), Support Vector Machine (SVM), Naïve Bayes (NB), RF, XGBoost classifier (XGB), Multilayer Perceptron (MLP) |
| 3. | Mboya et al, 2020 [27] | Prediction of perinatal death | Conventional Machine learning | ANN, RF, NB, bagged trees, Boosting and the logistic regression |
| 4. | Tarimo et al, 2021 [53] | Prediction of neonates with low Apgar scores after induction of labour in Northern Tanzania. | Conventional Machine learning | XGBoost, AdaBoost, Gradient Boosting, Decision-tree |
| 5. | Tarimo et al, 2021 [28] | Predicting the use of labor induction intervention | Conventional Machine learning | RF, logistic regression, Boosting, Bagging, ANN, Naïve Bayes |
| 6. | Ramkumar et al, 2020 [43] | Maintenance of optimal vaccine stocks | Conventional Machine learning | RF, Gradient boosting, KNN, ElasticNet, Support Vector regression, ARIMA, ANN |
| 7. | Mpapalika et al, 2020 [26] | Diagnosis and treatment of malaria | Deep learning | Neural Network |
| 8. | Bezu et al, 2021 [29] | Reduction of pregnant women bypassing nearby delivery healthcare services through a performance-based financial scheme | Not specified | Not specified |
| 9. | Bustreo et al 2019 [54] | Improvement in case management algorithms and quality of care | Not specified | Not specified |
| 10. | Milali et al, 2020 [30] | Estimation of parity status of wild mosquitoes from near-infrared spectra | Conventional Machine Learning | ANN |
| 11. | Lawrence, 2020 [31] | Prediction of stunting status among children under five years | Conventional Machine Learning | RF, KNN, Decision Tree, SVM,<br>LR |
| 12. | Deshpande et al, 2018 [38] | Identification of the most important predictors of (treatment) sputum conversion, ADR, and deaths in patients with pulmonary TB. | Machine Learning | RF, classification and regression tree (CART) |

| | | | | |
|---|---|---|---|---|
| 13. | Jehan et al, 2020 [37] | Prediction and prevention of preterm births (PTB) across different cohorts. | Machine Learning | RF |

ANN: Artificial Neural network, KNN: K-Nearest Neighbours, RF: Random Forest, LDA: Linear Discriminant Analysis, LR: Logistic Regression, SVM: Support Vector Machine, NB: Naïve Bayes, GB: XGBoost classifier, MLP: Multilayer Perceptron, AI: Artificial Intelligence.

**Table 2:** Grey literature showing existing AI-based innovations in the Tanzanian health sector

| **Author and year** | **Purposes and Area** |
|---|---|
| AI Commons, Sahara Ventures, and Tanzania AI Lab, 2020 [36] | Making artificial intelligence solutions work in Tanzania: lessons from IdeaLab-AI Project |
| Minja and Sundberg, 2021 [33] | Exploring stakeholdersô perceptions on the use of AI for health supply chains in Tanzania |
| Sundberg et al, 2021 [32] | Implementing AI in the Tanzanian health supply chain |
| Broadband Commission, 2020 [35] | Reimagining global health through artificial intelligence: the roadmap to AI maturity |
| UNDP Accelerator Lab Tanzania [34] | Using artificial intelligence to tackle 'infodemic' in Tanzania |

UNDP: United Nations Development Programme



**Appendix I: Search Queries (performed between August and November 2021 and then updated and rerun between July 2022 and August 2022).**

We conducted on the following databases and AI projects related websites

| **Database** | **Search log** | **Returned** |
|---|---|---|
| **PubMed** | (((((Tanzania[MeSH Terms]) OR (United Republic of Tanzania[Title/Abstract])) OR (Zanzibar[Title/Abstract])) OR (Tanzania)) OR (United Republic of Tanzania[Text Word])) AND ((((((Health) OR (Health symptoms[MeSH Terms])) OR (diseases diagnosis[Title/Abstract])) OR (health sector[Title/Abstract])) OR (Health care sector[Title/Abstract])) OR (Disease[Text Word]))) AND ((((((((((((((Artificial intelligence[MeSH Terms]) OR | **119** |

| | | |
|---|---|---|
| | (AI[Title/Abstract])) OR (Artificial intelligence[Title/Abstract])) OR (Machine Intelligence[Title/Abstract])) OR (Machine Intelligence)) OR (Computer Reasoning[Title/Abstract])) OR (Deep learning[Title/Abstract])) OR (Machine learning[Title/Abstract])) OR (Artificial intelligence based assessment[Title/Abstract])) OR (Artificial intelligence based assessment[Title/Abstract])) OR (Artificial intelligence-based assessment[Title/Abstract])) OR (AFYA)) OR (Artificial intelligence-based innovations[Title/Abstract])) OR (Artificial intelligence based innovations [Title/Abstract])) | |
| **EMBASE** | (('health'/exp OR 'health') OR 'health symptoms' OR 'diseases diagnosis' OR 'health sector' OR 'health care sector') AND (('artificial intelligence'/exp OR 'artificial intelligence') OR 'machine intelligence' OR ('automated reasoning'/exp OR 'automated reasoning') OR ('deep learning'/exp OR 'deep learning') OR 'machine learning' OR 'artificial intelligence based assessment' OR 'artificial intelligence-based innovations') AND (('tanzania'/exp OR 'tanzania') OR ('united republic of tanzania'/exp OR 'united republic of tanzania') OR Zanzibar) | **79** |
| **Google Scholar** | 'health symptoms' OR 'diseases diagnosis' OR 'health sector' OR 'health care sector' AND 'artificial intelligence' OR 'machine intelligence' OR 'automated reasoning' OR 'automated reasoning' OR 'deep learning' AND Tanzania OR 'United Republic of Tanzania) | **1,820** |
| **Institution/Projects Websites** | https://www.broadbandcommission.org/, https://saharaventures.com/, https://www.undp.org/tanzania/, https://www.macro-eyes.com/ https://insupplyhealth.com/ | **5** |

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**Author contribution**

Please specify the contribution of each author to the paper, e.g. study design, data collections, data analysis, writing, others, who have contributed in other ways should be listed as contributors.

FS, and DM were responsible for the concept and design. FS, DM, RB and DS did the study selection. FS, RB, DM and DS did the data extraction, critical appraisal, and coding. FS and DM drafted the manuscript. All authors critically revised the manuscript for intellectually important content and verified the underlying data.

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