EMPOWERING AGRICULTURE, HEALTH, EDUCATION, FINANCE, PEACE, AND GOVERNANCE THROUGH ARTIFICIAL INTELLIGENCE AND EMERGING TECHNOLOGIES

BOOK OF ABSTRACTS

AI4SD2026

INTERNATIONAL CONFERENCE ON:

AI FOR SUSTAINABLE DEVELOPMENT IN AFRICA

APRIL 27-28, 2026 - MEKELLE, ETHIOPIA

INTERNATIONAL CONFERENCE ON:

AI FOR SUSTAINABLE DEVELOPMENT IN AFRICA

April 27-28, 2026

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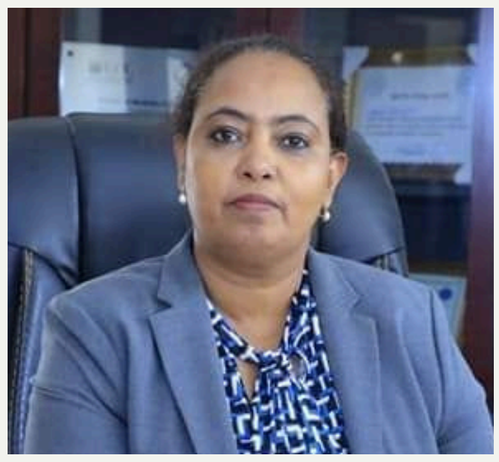

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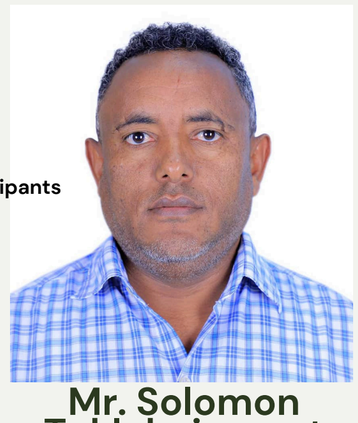

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Mr. Yemane Seged
member

Dr. Tesfaye Messele
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Dr. Hailay Mehari
member

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Message from the President, Mekelle University

Fana Hagos (PhD)

Distinguished Guests, Esteemed Researchers, and Honored Participants,

It is my great pleasure to welcome you to the *International Conference on Artificial Intelligence for Sustainable Development in Africa (AI4SD 2026)*. Hosted by Mekelle University, this event marks a landmark moment in our institution's journey as a hub for academic excellence and technological innovation.

Artificial Intelligence is rapidly transforming the global landscape, offering unprecedented opportunities to address critical challenges in agriculture, health, education, finance, energy, and governance. At the same time, it raises important questions regarding ethics, security, inclusiveness, and responsible deployment. We must ensure that these advancements are governed by robust ethical frameworks and remain inclusive of all segments of society. This conference has been carefully designed to address both the opportunities and responsibilities associated with AI, aligning technological advancement with sustainable development priorities.

AI4SD 2026 serves as a high-level platform that brings together researchers, policymakers, industry leaders, and development partners to exchange knowledge, foster collaboration, and promote innovation. It reflects Mekelle University's strategic commitment to advancing research excellence, digital transformation, and societal impact, while contributing to national priorities and continental development agendas. By aligning cutting-edge technological inquiry with sustainable development priorities, we are moving beyond theory into the realm of actionable impact.

We are particularly proud that this conference emphasizes locally relevant, inclusive, and ethical AI solutions that respond to Africa's unique context. By connecting scientific research with practical applications and panel discussions, AI4SD 2026 aims to generate meaningful and lasting contributions to sustainable development.

I would like to express my sincere appreciation to all contributors, organizers, partners, and participants for their dedication and support in making this conference possible.

I wish you all an inspiring and productive conference. May the dialogues started here in Mekelle spark the partnerships and innovations that will define a prosperous, digitally empowered Africa.

Dr. Fana Hagos
President, Mekelle University

KEY MESSAGES

Message from the Vice President for Research & Community Engagement (VPRCE), Mekelle University

Eyasu Yazew (PhD)

Dear Respected Conference Participants,

It is with a strong sense of duty and institutional commitment that I address this distinguished gathering on the occasion of the International Conference on Artificial Intelligence for Sustainable Development in Africa (AI4SD 2026), hosted by Mekelle University.

The convening of this conference is both timely and necessary. Artificial Intelligence is rapidly emerging as a defining driver of socio-economic transformation, with far-reaching implications across agriculture, health, education, energy, finance, industry and governance. In this context, the establishment of a structured and high-level platform for dialogue, knowledge exchange, and collaboration is not optional; it is imperative. Such a platform ensures that the development and application of AI are guided by national priorities, informed by ethics-based evidence, and aligned with the broader objectives of sustainable development.

Over the past months, we have led the supervisory and organizational processes of this conference with a clear strategic mandate: to position Mekelle University at the forefront of research, innovation, and policy engagement in Artificial Intelligence. The realization of this conference reflects a coordinated institutional effort, bringing together academic leadership, expert committees, and strategic partners to deliver a platform of both national relevance and international standing.

I am particularly inspired by the diverse voices represented here, from seasoned experts to emerging scholars, and from local innovators to international leaders. The exchange of ideas you will engage in during keynote sessions, technical presentations, and interactive panels will surely catalyze new partnerships and pave pathways for impactful solutions that address real-world challenges.

This conference has been purposefully designed to move beyond conventional academic exchange. It connects research with policy, innovation with implementation, and knowledge with impact, enabling ideas to translate into solutions that address pressing societal challenges. By strengthening our collaborations and institutional frameworks, we are paving the way for evidence-based policy and socio-economic development across Africa. We measure our success through the partnerships we create and the real-world solutions we deliver. Let us work as one to turn these visionary insights into a digital reality for our continent.

On behalf of the entire University community, I extend my heartfelt gratitude to all for their attendance and valuable contributions. My utmost appreciation also goes to the conference organizing committee that worked day and night to make this topical event a success!!
With warm regards,

Eyasu Yazew Hagos (PhD)
Vice President for Research and Community Engagement
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Integrating AI and Geospatial Analysis to Assess Cactus Pear Cultivation Potential for Post-War Food Security in Eastern Tigray, Ethiopia

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Abstract

Cactus pear *(Opuntia ficus-indica)* is a drought-tolerant crop essential for household food security in semi-arid regions. The 2020–2022 Tigray conflict disrupted agricultural systems, threatening livelihoods in Eastern Tigray. This study integrates Artificial Intelligence and geospatial analysisto assess cactus pear cultivation potential in Kihen,Hayelom, and Mesanu tabias of Tsirae-Wemberta Woreda. Remote sensing, GIS layers (land use, slope, soil, climate), and household survey data (n=400) were analyzed using Random Forest machine learning to identify optimal cultivation zones and evaluate contributions to post-war food security. Elevation (Mean Decrease Accuracy = 28.4), soil depth (24.2), slope (22.8), market distance (19.6), and land holding (18.2) were identified as the most important factors influencing cactus cultivation. The Random Forest model achieved 77.6% overall accuracy (AUC = 0.842), significantly outperforming conventional MCDA-AHP (68.2%). Suitability analysis revealed that 19.0% (2,845 ha) of the study area is highly suitable(S1) for cactuspear cultivation, 34.9% (5,236 ha) moderately suitable(S2), 32.1% (4,812 ha) marginally suitable(S3), and 14.0% (2,107 ha) unsuitable (N). Currently, 68% of households grow cactus, with 94% consuming fruits (averaging 45 fruits/week) and 42% selling products (average income 4,850 Birr/year). Households cultivating cactus pear had significantly higher Food Consumption Scores (42.5) compared to non- cultivating households (28.3, $p<0.01$). Strategic expansion could increaseproduction 24-fold to 118,800 quintals/year, potentially benefiting 5,400 households. This study providesthe first high-resolution, AI-based cactus pear suitability map for Ethiopia, demonstrating the value of integrating machine learning with geospatial analysis for post-conflict agricultural planning.

Keywords: *Cactus pear; Artificial Intelligence; Random Forest;GIS; Land suitability; Food security; Post-warrecovery*

Data Driven Prediction of Sesame Yield Using Remote Sensing Time-Series Vegetation Indices and Climate Variables in Kafta Humera, Western Tigray

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Abstract

Accurate, timely yield prediction is essential for managing Ethiopia's vital sesame sector, which provides critical foreign exchange but is vulnerable to climate variability. This study develops and validates a high-resolution, field-scale yield prediction model for sesame using Sentinel-2 (10–20 m) imagery integrated with climate variables. Monthly NDVI time-series data (July–October 2019) from 100 sampled fields were analyzed in Ethiopia's primary sesame-producing district, Kafta Humera, Western Tigray, and reference evapotranspiration (ETo) was calculated to capture atmospheric water demand. Simple regression analysis identified August NDVI as the strongest single predictor ($R^2 = 0.420$), coinciding with flowering and early capsule filling stages. Stepwise multiple regression yielded an optimized model (Yield = 456.12 + 525.90×NDVI_Aug + 209.75×NDVI_Oct – 12.11×ETo_Sep + 83.96×NDVI_Jul + 7.45×ETo_Jul), explaining 70.5% of the variability in sesame yield. Five-fold cross-validation confirmed the model's robust performance (mean $R^2 = 0.705 \pm 0.090$, RMSE = 21.8 ± 3.1 kg ha^{-1}), corresponding to a 5.3% prediction error. Integrating multi-temporal vegetation indices with climate variables improved yield prediction accuracy compared with single-indicator models. The model provides early field-level yield forecasts approximately 8–10 weeks before harvest, offering a scalable decision-support tool for enhancing climate resilience and productivity in smallholder sesame systems.

Keywords: *Sesame yield prediction; Sentinel-2; Vegetation indices (NDVI); Reference evapotranspiration (ETo); Smallholder agriculture*

Enhancing Water Security through Early Coffee Disease Detection Using deep learning to Reduce Pesticide Use and Water Pollution and increase soil fertility

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Abstract

Agriculture is the backbone of the Ethiopian economy, contributing more than 80% of national income, with coffee cultivation and export representing one of its most vital sectors. However, coffee production is severely constrained by diseases that reduce yield, quality, export earnings, and foreign exchange revenue. Coffee diseases arise from both biotic and abiotic factors, including coffee leaf rust, coffee wilt disease, coffee berry disease, and insect infestations. Previous research on automated coffee disease classification has largely focused on biotic causes, while the role of abiotic factors particularly insect-related damage has received limited attention. This study develops an automated coffee disease classification system that detects both biotic and abiotic stressors affecting coffee plants. The system classifies coffee leaf rust, coffee wilt disease, coffee berry disease, insect damage on coffee berries, and healthy leaves and berries. A comprehensive dataset of 5,000 images was compiled from major coffee-producing regions, with 1,000 images per class. The model was developed using image processing, feature extraction, and machine learning–based classification techniques. Performance was evaluated using accuracy, precision, recall, F1 score, and confusion matrix metrics. Results show progressive improvement in classification performance, achieving 74% accuracy with raw data, 83% accuracy with Gaussian filtering, and 95% accuracy with K-means segmentation. These findings demonstrate the effectiveness of enhanced preprocessing techniques for improving detection of both biotic and abiotic coffee diseases. Beyond technological advancement, the proposed system contributes to water security by enabling early and precise disease detection, reducing excessive pesticide use, preserving water quality, and supporting environmentally sustainable farming. The approach also advances precision agriculture and climate-smart water management, enhancing coffee yield, quality, and long-term ecosystem health.

Keywords: *Coffee diseases; Deep learning; Biotic and abiotic factors; Precision agriculture; Sustainable water management*

Integrated Remote Sensing and Machine Learning Prediction of Water Deficit Index (WDI) for Enhancing Water Resource Management in Rain-fed and Groundwater Irrigated Agriculture of Mekoni Sub-basin, Raya Valley

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Abstract

Water scarcity and inefficient irrigation practices pose significant challenges to sustainable agriculture, necessitating advanced solutions for optimizing water use. Accurate prediction of water deficit and crop water requirement is essential for efficient and smart irrigation management, reducing water wastage, and improving crop yield. This study explores the integration of Machine Learning (ML) and remote sensing for the direct estimation of Water Deficit Index (WDI) in rain-fed and groundwater-irrigated systems in Mekoni Sub-basin of Raya Valley. By utilizing spatiotemporal MODIS and the University of Idaho's Terra-Climate monthly datasets spanning from 2015–2024, we evaluated the performance of various Machine Learning (ML) algorithms, including Random Forest (RF), eXtreme Gradient Boosting (XGBoost), and Support Vector Regression (SVR). The ML model comprises 17 continuous predictor variables and a 5-fold cross-validation is applied to improve model performance. The comparative study evaluates each model's accuracy using key metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and Coefficient of Determination (R^2). Results indicate that XGBoost model consistently achieved superior accuracy (MSE = 0.0003, RMSE = 0.0180, MAE = 0.0134 and R2 = 0.9495) with very good Generalization Gap (17.71%) in characterizing WDI under heterogeneous conditions, capturing the general trend of the Water Deficit Index without fitting to specific "noisy" months. The findings underscore the potential of ML-driven WDI monitoring integrated with satellite remote sensing data as a cost-effective decision-support tool for sustainable water resource management while enhancing crop yield.

Keywords: *Machine Learning (ML) models; Remote sensing; Water Deficit Index (WDI); Irrigation efficiency; Satellite imagery; Precision irrigation; Climate change resilience*

A Bi-Directional integration of Satellite-UAV Remote Sensing for Adaptive and Efficient Precision Agriculture

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Abstract
Precision agriculture increasingly relies on satellite and unmanned aerial vehicle (UAV) remote sensing to monitor crop variability and optimize farm management. However, current operational workflows treat these platforms as independent systems, resulting in redundant full-field UAV surveys, inefficient UAV mission planning, and elevated operational costs. This study proposed a hierarchical, bi-directional integration framework that systematically links satellite-derived analytics with intelligence-driven UAV deployment. In the proposed architecture, multispectral satellite imagery is first processed to generate thematic layers (e.g., NDVI (Normalized Difference Vegetation Index), moisture stress indicators, crop variability maps) that identify spatial heterogeneity across entire fields. Regions of Interest (ROIs) are then extracted using segmentation and clustering techniques and transferred as georeferenced inputs into UAV mission planning software. Instead of uniform coverage, UAV operations become adaptive and spatially selective, with optimized flight parameters tailored to diagnostic objectives. A case study employing NDVI-based ROI segmentation demonstrated that less than 20% of total field area required UAV inspection. Targeted deployment reduced flight duration, energy consumption, and data volume by over 80%, while improving thematic coherence and machine learning compatibility. Furthermore, UAV-derived high-resolution data were shown to support calibration and refinement of satellite-based analytical models, establishing a closed-loop sensing ecosystem. The results confirm that hierarchical satellite–UAV integration enhances efficiency, reduces costs, improves analytical robustness, and advances scalable, intelligence-driven precision agriculture systems.

Keywords: *Adaptive mission planning; Intelligence-driven remote sensing; Multi-scale data fusion; NDVI; Precision agriculture; ROI segmentation; Satellite–UAV integration*

From Systematic Review to a Localized Edge-AI Solution: Addressing Post-Harvest Losses for Sustainable Agriculture in Tigray, Ethiopia

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Abstract
Post-harvest losses (PHL) in Tigray, Ethiopia reach 25-35% of cereal harvests due to inadequate storage. This paper presents a systematic review of 57 sources on PHL and digital mitigation technologies, revealing a pronounced localization deficit: existing AI/IoT solutions assume reliable connectivity, stable power, and digital literacy, conditions absent in smallholder contexts. No reviewed study simultaneously addresses hardware localization, region-specific datasets, edge-optimized models, and culturally adapted interfaces. Based on these gaps, a research proposal for a localized Edge-AI framework is presented. Expected outcomes include low-cost sensor pods, localized datasets, edge-AI models, and Tigrigna-language interfaces. This paper reports only the review and proposal phases; no implementation results are presented.

Keywords: *Post-harvest losses; Systematic review; Edge-AI; TinyML; Localization; Food security;Internet of things*

TRACK : ARTIFICIAL INTELLIGENCE IN EDUCATION

Artificial Intelligence Literacy and Utilization among Higher Education Instructors in Ethiopia: A Mixed-Methods Inquiry

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Abstract

This study investigated the state of artificial intelligence (AI) usage and literacy among higher education instructors in selected public universities of Ethiopia through a mixed-methods approach. The research explored the extent of instructors' familiarity with generative AI (GenAI), their purposes of use, AI literacy levels across four dimensions, awareness, usage, evaluation, and ethics, and differences based on gender, age, and teaching experience. Quantitative data were collected from 376 faculty members via a structured questionnaire and analyzed using descriptive statistics, t-tests, and ANOVA, while qualitative data were gathered through eight individual interviews and four focus group discussions involving 32 participants. Quantitative findings showed that 85.9% of respondents were familiar with AI and 91.7% had used AI tools, mainly for teaching and learning (66.6%), research (54.6%), and personal purposes (42.7%). Mean scores indicated a moderate level of AI literacy (M = 3.52–3.66). Gender and experience significantly influenced awareness and usage ($p < .05$), with younger and less experienced instructors reporting higher engagement. Qualitative results revealed that instructors perceived AI as both beneficial and challenging: it enhances efficiency in teaching, grading, and information access but also risks academic integrity and dependency. Participants emphasized the need for continuous AI training and institutional readiness, particularly in infrastructure, internet access, and ethical guidance, to effectively integrate AI into academic practices. Overall, the study highlights a growing openness toward AI use among Ethiopian faculty but underscores the need for strategic capacity building and ethical awareness to ensure responsible and equitable adoption in higher education.

Keywords: Artificial intelligence literacy; Generative AI; Higher education; Mixed method; Ethiopia

Digital Divide and Artificial Intelligence Adoption in Ethiopian Higher Education Institutions

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Abstract

Artificial Intelligence (AI) has emerged as a transformative force in global higher education, enabling adaptive learning, intelligent tutoring, predictive analytics, and data-driven institutional management; however, its adoption in Ethiopian higher education institutions remains limited and uneven. This study aims to examine how the digital divide influences AI integration, focusing on infrastructural, institutional, and governance-related factors. A convergent parallel mixed-methods design was employed, combining qualitative document analysis of national policies, institutional strategies, and international frameworks with quantitative assessment of ICT infrastructure, broadband access, and digital literacy indicators. For data analysis, qualitative data were examined using thematic analysis, involving coding, categorization, and identification of key patterns, while quantitative data were analyzed using descriptive statistics (frequencies, percentages, and comparative indicators) to assess levels of digital access and readiness. The findings reveal five major barriers: inadequate infrastructure readiness, limited digital competencies among faculty and students, financial constraints, weak governance and ethical frameworks, and uneven institutional opportunities for AI implementation. Specifically, limited broadband penetration, high connectivity costs, unequal access to ICT resources, and insufficient digital literacy significantly constrain AI adoption, while underdeveloped regulatory frameworks raise concerns regarding transparency, equity, and data privacy. The study concludes that digital inequality is a critical barrier to AI readiness in Ethiopian higher education. Therefore, it recommends targeted policy interventions, increased investment in digital infrastructure, strengthened capacity-building initiatives, and the development of robust governance and ethical frameworks to ensure equitable, effective, and sustainable AI integration in the higher education system.

Keywords: *Artificial Intelligence; Higher education; Digital divide; Ethiopia; ICT infrastructure; Policy and governance*

Reimagining the Future of Higher Education: Digital Transformation and Immersive Technologies for Virtual Learning in a 21st-Century Changing World — A Systematic Review and Meta-Analysis

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Abstract

In a rapidly evolving world shaped by technological advancement and global disruptions such as COVID-19, higher education is experiencing a profound digital transformation. Digitalization and digital transformation through virtual learning environments, AI-driven adaptive platforms, and IoT-enabled educational tools are redefining teaching, learning, and access. This systematic review and meta-analysis examined the impacts of digitalization and digital transformation via virtual learning (DDVL) on higher education outcomes in a changing world. Following PRISMA 2020 guidelines, data were synthesized from 84 studies (2010–2025) involving 78,426 participants across 30 countries, with 47 studies included in the quantitative meta-analysis. A random-effects model revealed a moderate, significant positive impact of DDVL on higher education outcomes (Hedges' $g = 0.52$; 95% CI: 0.36–0.68; $p < 0.001$). Subgroup analysis indicated stronger effects among students with disabilities ($g = 0.66$) and rural or low-income learners ($g = 0.51$). Mobile learning ($g = 0.61$), AI-driven adaptive systems ($g = 0.57$), and Universal Design for Learning (UDL)-integrated learning platforms ($g = 0.48$) demonstrated the greatest effectiveness. DDVL interventions improved course completion by 30%, student engagement by 25%, and access among rural learners by 40%. Study heterogeneity was moderate ($I^2 = 68.4\%$). The findings reveal that robust DDVL frameworks significantly enhance educational outcomes, inclusivity, and access. When underpinned by inclusive design principles, digital learning technologies offer scalable, equitable, and sustainable pathways to resilient higher education systems.

Keywords: *Accessibility; Adaptive systems; Digital inequality; Inclusivity; Virtual learning*

Systematic Literature Review on Artificial Intelligence in Education: Opportunities, Challenges, and Future

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Abstract

Artificial Intelligence (AI) is rapidly transforming education globally, offering opportunities to enhance teaching, learning, and administrative processes. In Ethiopia, where the education system faces challenges such as limited access, teacher shortages, and infrastructure gaps, AI presents a potential solution to improve quality, equity, and efficiency. This systematic literature review examines the current state of AI integration in Ethiopian education, synthesizing studies published between 2018 and 2025. Using structured search strategies across academic databases, open-access repositories, and policy documents, relevant literature was selected based on its focus on AI applications, teacher readiness, curriculum implications, and policy frameworks. The review highlights that AI has the potential to provide personalized and adaptive learning, support data-driven decision-making, enhance administrative efficiency, and promote research and innovation in higher education. Universities in Ethiopia are gradually adopting AI tools in areas such as automated grading, plagiarism detection, intelligent tutoring systems, and learning management. However, the integration remains uneven due to infrastructural limitations, limited teacher capacity, financial constraints, and ethical and policy challenges. Furthermore, curricula often lack AI-relevant content, and rural-urban disparities exacerbate inequalities in access and use. The study identifies significant gaps in research on locally relevant AI applications, ethical frameworks, and inclusive implementation strategies. Future directions emphasize the need for national AI policies, capacity-building initiatives for teachers, investment in digital infrastructure, curriculum reform, and collaborative research to ensure culturally appropriate and scalable AI solutions. By addressing these challenges strategically, Ethiopia can leverage AI to enhance educational quality, equity, and relevance, preparing learners for the demands of the 21st-century digital economy.

Keywords:*Artificial Intelligence; Ethiopian education; Teacher readiness; Curriculum; Educational technology*

TRACK : ARTIFICIAL INTELLIGENCE IN FINANCE

Leveraging AI for Financial Inclusion and Stability: A Framework for Ethiopia's Sustainable Development

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Abstract

The study examines how Artificial Intelligence (AI) in Ethiopia's financial sector, when combined with sustainable service automation and fraud detection systems, can improve financial development. The study investigates how AI-based financial analytics and intelligent access can help organizations meet regulatory obligations while supporting economic growth. Through its mixed-methods approach, which includes case studies and policies of Ethiopian fin-tech projects, the study presents an artificial intelligence model that incorporates ethical practices, data protection measures, and. The proposed framework demonstrates potential to increase financial access by 30-40% while reducing fraud losses through AI solutions. The results demonstrate how AI drives digital transformation, helps Small and Medium Enterprises (SMEs) grow, mitigates financial risks, and highlights the need for … responsible governance to address exclusion and bias. The research advances policy discussions on AI applications for Ethiopia's digital economy development, emphasizing innovation as a driver of sustainable economic growth. Financial inclusion is a key driver of economic growth, poverty reduction, and resilience. In Ethiopia, account ownership has grown to approximately 49%, yet mobile money adoption remains below 10%. Women constitute 58% of the unbanked population, and nearly 80% of excluded adults live in rural areas. These structural gaps limit equitable development and pose risks to sustainable growth.

Keywords: *Artificial Intelligence; Financial inclusion; Ethiopia; Fraud detection; Ethical AI; Digital transformation*

Exploring the Role of Artificial Intelligence in Shaping Socio-Economic Development for Developing Countries

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Abstract
Artificial Intelligence (AI) is a driving force for socio-economic development, particularly in underdeveloped regions, by offering opportunities to improve education, healthcare, agriculture, and infrastructure. This study examines the role of AI in advancing socio-economic development in the Aari Zone of Southern Ethiopia. It provides a detailed assessment of the region's current socio-economic conditions, such as poverty levels, healthcare access, and educational infrastructure, and distinguishes the major challenges the community faces. Initially, key areas--agriculture, healthcare, and education, where AI technologies could bring significant enhancements were identified. Accordingly, sector-specific issues and AI solutions were determined based on the national and international AI strategies for advancing socioeconomic development. In data analysis and visualization, Python and its associated libraries were employed. Quantitative and qualitative data collection techniques and a stratified sampling methodology were implemented to provide a comprehensive assessment of the role of AI in socio-economic development. The study also evaluated the results of the Artificial intelligence initiatives through both qualitative and quantitative measures, looking at their effects on living standards, economic resilience, and access to essential services. The study overcomes important development challenges and provides data-driven strategies for the effective use of AI.The findings lead to real-world recommendations for policymakers and stakeholders, offering a clear guide for using AI technologies to support sustainable socio-economic development in the Aari Zone of Southern Ethiopia, and comparable regions.

Keywords:*Artificial Intelligence; Ethiopian education; Teacher readiness; Curriculum; Educational technology*

Automatic Classification of Financial Service (FinTech) Reviews in Ethiopia Using NLP and Deep Learning

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Abstract

The rapid expansion of Financial Technology (FinTech) services in Ethiopia has generated large volumes of multilingual user feedback across digital platforms. However, these reviews remain largely underutilized due to their unstructured nature, code-switching patterns, and linguistic diversity. This study presents a comprehensive multilingual automatic classification framework for Ethiopian FinTech user reviews using Natural Language Processing (NLP), traditional machine learning and deep learning models. A dataset of 8,387 reviews collected from major Ethiopian FinTech applications was manually labeled into five categories: General Praise or Suggestions (GPS), Login and Access Problems (LAP), Service and Support Complaints (SSC), Transaction and Payment Failures (TPF), and User Experience Design issues (UXD). Seven models were evaluated, including SVM, Random Forest, XGBoost, Sequential Neural Network, CNN, LSTM, and BiLSTM. Experimental results demonstrate that deep learning models significantly outperform traditional models, particularly after addressing class imbalance through oversampling. The CNN model achieved the highest accuracy (95%) and macro F1-score (94%) after balancing. The findings provide actionable insights for improving digital financial services in Ethiopia and contribute a localized multilingual dataset and provide a scalable framework for FinTech review intelligence in low-resource language settings.

Keywords: *Ethiopian FinTech; NLP; Deep learning; Code-switched text; Review classification; User feedback analytics; Financial inclusion*

Fostering Sustainable Development of Finance Sector through Financial Technology (Fin Tech) Innovation: A Systematic Literature Review

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Abstract

In the current global case, Financial Technology (Fin Tech) is very crucial for sustainable development and long-term economic growth through different ways of transforming the economy. However, there is a gap and limitation in the existing literature on the financial technology innovations boosting sustainable development, interconnected between financial technology and Sustainable Development, as well as its impact on long-term economic growth and sustainable development. In order to bridge and address this gap and limitation, this study undertakes a systematic literature review by examining and investigating Fostering sustainable development through financial Technology (Fin Tech) Innovation based on the encompassing of 110 journal articles spanning from 2017-2025, sourced from Scopus and Google Scholar. To ensure a focused review, four inclusion criteria were applied: (1) papers published between 2017 and 2025, (2) alignment with disciplines like finance and business as well as finance and economics, (3) inclusion of research articles (excluding books, chapters, and reports), and (4) English-language articles with all open-access availability. Following the proper PRISMA framework, the remaining 110 articles were downloaded and stored in Mendeley for in-depth content analysis. This study aims to investigate and examine the significant studies that were reviewed and analyzed the integration of combining financial technology, the digital financial service industry, innovation, and socio-economic development to provide and build sustainable development through financial technology innovation.

Keywords: *Finance; Finance sector; Financial technology; Innovation; Sustainable development*

Investment Limitation and Sharia Compliance Regulation of Interest-Free Banking in Ethiopia

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Abstract

The interest-free banking market has been expanding in the Ethiopian financial system since its emergence in 2011. Through the years until now, the need to closely watch its operation in the context of local circumstances and put in place a corresponding regulatory framework has become pressing. The National Bank of Ethiopia (NBE) has issued several directives, mostly as amendments to the previous ones, so as to incorporate the new concerns brought forth by the new Islamic banking sector of the general Islamic Financial Service Industry (IFSI). Besides divulging the state of practice by full-fledged interest-free banks and interest-free windows of conventional banks, the paper examines two major areas in the regulation of the sector in Ethiopia in light of the best practices of jurisdictions and recommendations of standard-setting institutions of the industry. These areas of regulatory concern are Sharia compliance and investment limitation. The paper investigates directives of the NBE and identifies the regulatory gaps in addressing the risks arising from Sharia non-compliance and investment ventures of interest-free banks in the country.

Keywords: *Prudential regulation; Sharia compliance; Investment limitation; Interest-free banking; Conventional banking*

TRACK : ARTIFICIAL INTELLIGENCE IN HEALTH

Hybrid Cross-Modal Attention Network for Early Breast Cancer Detection in Low-Resource Clinical Settings

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Abstract

Breast cancer is the leading cause of cancer-related mortality among women in Sub-Saharan Africa, where delayed diagnosis results from limited radiology expertise and fragmented clinical data systems. Although deep learning models have demonstrated strong performance in mammographic analysis, most rely solely on imaging data and are trained on Western populations, limiting their applicability in African healthcare settings. This paper presents a Hybrid Cross-Modal Attention Network (HCMAN) that integrates mammogram images with structured clinical data using transformer-based cross-modal attention mechanisms. The model was developed and validated using a locally collected dataset of 2,560 mammogram images from 1,024 patients across four Ethiopian referral hospitals, with biopsy-confirmed ground truth labels. The proposed framework achieves 97.8% accuracy, 97.2% sensitivity, 98.3% specificity, and an AUC of 0.987, significantly outperforming image-only baselines. The system demonstrates robustness to low-quality images typical of resource-limited settings, with only 3.2% performance degradation compared to 8.7% for image-only models. Cross-modal attention analysis reveals clinically appropriate behavior: higher reliance on clinical features for ambiguous cases such as dense breasts and young patients. The model's lightweight architecture enables deployment on standard hospital workstations (<2 seconds inference on CPU). This work advances sustainable, context-aware AI solutions for equitable breast cancer diagnostics in Africa.

Keywords: *Breast cancer detection; Multimodal deep learning; Cross-modal attention; Medical imaging, Low-resource healthcare; AI for sustainable development*

Interpretable machine learning for predicting birth asphyxia: A prospective cohort study in Tigray, Ethiopia

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Abstract

Birth asphyxia is the second leading cause of neonatal mortality in Ethiopia, contributing to preventable morbidity and long-term neurodevelopmental impairment. In low-resource regions such as Tigray, timely identification of newborns at risk remains a challenge. This prospective cohort study recruited 1,014 mother–newborn pairs across four hospitals in Tigray (February–April 2025) to develop supervised machine learning models for early prediction of birth asphyxia. After preprocessing, feature selection, and class balancing, seven algorithms were trained and evaluated. The random forest classifier achieved the best performance (AUC = 0.99, Brier score = 0.0099), with Shapley additive explanations (SHAP) confirming fetal heart rate, birth weight, malpresentation, hypothermia, referral status, and prolonged labor as the most influential predictors. Nearly 80% of predictive capacity was explained by these clinically actionable variables. The findings demonstrate that interpretable machine learning models can support routine labor management and timely interventions, offering a scalable solution to reduce neonatal mortality in low-resource settings.

Keywords:*Birth asphyxia; Neonatal health; Supervised machine learning; Predictive modeling; Ethiopia; Sustainable development*

OPTED: Open Preprocessed Trachoma Eye Dataset Using Zero-Shot SAM 3 Segmentation

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Abstract

Trachoma remains the leading infectious cause of blindness worldwide, with Sub-Saharan Africa bearing over 85% of the global burden and Ethiopia alone accounting for more than half of all cases. Yet publicly available preprocessed datasets for automatedtrachoma classification are scarce, and none originate from the most affected region. Raw clinical photographs of everted eyelids containsignificant background noisethat hinders direct use in machinelearning pipelines. We present OPTED, an open-source preprocessed trachoma eye dataset constructed using the Segment Anything Model 3 (SAM 3) for automated region-of-interest extraction. We describe a reproducible four- step pipeline: (1) text-prompt-based zero-shot segmentation of the tarsal conjunctiva using SAM 3, (2) background removal and bounding-box cropping with alignment, (3) quality filtering based on confidence scores,and (4) Lanczosresizing to 224×224 pixels. A separate prompt-selection stage identifies the optimal text prompt, and manual quality assurance verifies outputs. Through comparison of five candidate prompts on all 2,832 known-label images, we identify “inner surface of eyelid with red tissue” as optimal, achieving a mean confidence of 0.872 (std 0.070) and 99.5% detectionrate (the remaining13 images are recovered via fallback prompts). The pipeline produces outputs in two formats: cropped and aligned images preserving the original aspect ratio, and standardized 224 × 224 images ready for pre- trained architectures. The OPTED dataset, preprocessing code, and all experimental artifacts are released as open source to facilitate reproducible trachoma classification research.

Keywords: *Trachoma; Image segmentation; Dataset preparation; Segment Anything Model; Open-source dataset; Medical image preprocessing*

Machine Learning Prediction of Child Stunting and Wasting in Ethiopia Using DHS Data: XGBoost and Random Forest Models with SHAP Interpretability

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Abstract

Child malnutrition remains one of the biggest issues in global public health. Machine learning has real potential for forecasting health trends but putting it to work on tricky survey data that represents whole nation's calls for strong approaches. Conventional statistical models often lack sufficient capacity to describe the complex interrelations between the various social, demographic, and environmental determinants. Our objective was to construct accurate machine learning (ML) models for stunting and wasting in children <5 y of age from a nationally representative sample and to determine principal modifiable risk factors associated with both. We used 2016 Ethiopia Demographic and Health Survey (EDHS) data, which included 10,641 children under five years of age as a sample, and trained RF models and XGBoost models. SHAP (SHapley Additive exPlanations) values and Partial Dependence Plots (PDPs) were employed for feature importance and model interpretability. XGBoost always outperformed Random Forest in all the performance measures, considering stunting and wasting. For stunting, XGBoost provided an Area Under the Receiver Operating Characteristic Curve (AUC) of 0.82, and Random Forests had an AUC of 0.79. For wasting, XGBoost achieved an AUC of 0.76 while the Random Forest's approximated AUC was 0.71. Selected key modifiable predictors by SHAP values were- Household wealth index (SHAP value: 0.19), Maternal education (SHAP value: 0.17), and sanitation access (SHAP value: ~0.14). Machine learning models predicted child malnutrition risk accurately, especially XGBoost. The study provides a robust, interpretable framework for predicting child malnutrition risk, demonstrating the utility of integrating machine learning with complex survey data to guide targeted public health interventions. The methodological approach underscores the importance of socioeconomic and environmental drivers like household wealth, maternal education, and sanitation.

Keywords: *Machine learning; Child malnutrition; Stunting; Wasting; XGBoost; SHAP; DHS*

Saving Little Lives Assist (SLL-Assist) AI: Lessons from Usability and Feasibility Test of a Novel Artificial Intelligence Application to Improve Access to Content on Maternal and Newborn Care

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Abstract

A multi-disciplinary team designed Saving Little Lives Assist (SLL-Assist), a document-bound artificial intelligence (AI) application to improve access to the comprehensive library of WHO-approved maternal and newborn content. We investigated the usability and feasibility of SLL-Assist among healthcare providers in four hospitals of Tigray, Ethiopia. Feedback was collected via WhatsApp. Subsequently, the Post-Study System Usability Questionnaire (PSSUQ) covered three sub-scales consisting of six items, in which the seven-point Likert scale and System Usability Scale were used. One hundred eighty Healthcare providers participated in the post-use survey. The average age of participants was 34 years, with 74% being female, 58% undergraduate midwives, and 30% undergraduate nurses. Out of the 36-maximum score, participants scored of 12.5 for usefulness, 11.8 for information quality, and 13.7 for interface quality. Most participants (74%) found it easy to amend queries, 98% said the information was clear, and 92% agreed it was easy to locate what they needed. Additionally, 84% reported high satisfaction with SLL-Assist. Use of a purpose-designed AI-enabled application for accessing WHO-approved maternal and newborn healthcare content was acceptable and feasible in low-resource settings. There are demands for AI solutions that can work in offline settings and in local languages.

Keywords: *Usability; feasibility; Artificial Intelligence (AI); Newborn care; Neonatal mortality*

Resilience through Inclusive Self-care and Emotional Well-being (RISE) for Healthcare Professionals in Tigray- An AI-assisted tool

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Abstract
Healthcare workers in post-conflict settings face high levels of stress, trauma exposure, and emotional burden, yet access to context-appropriate self-care and wellbeing support remains limited. This study assessed the acceptability, usability and perceived effects of the AI-assisted RISE mobile application among healthcare workers in Tigray, Ethiopia, under the Resilience through Inclusive Self-Care and Emotional Wellbeing for Healthcare Professionals in Tigray (RISE) project. The project developed a self-care guide in Tigrigna, Amharic, and Afan Oromo, which informed the mobile application; in Tigray, the intervention focused on the Tigrigna version. A pre- and post-intervention evaluation was conducted as part of the project monitoring and evaluation framework among 160 randomly selected healthcare workers from four health institutions. Data were collected using Kobo-based tools, and post-intervention analysis was done. Eighty-six participants completed the post-test. Results showed that over 80% of participants demonstrated improved knowledge of stress and self-care, 77% reported applying at least one self-care practice in daily work, and 91% reported improved overall wellbeing. Satisfaction reached 88%, while 86% reported feeling comfortable or very comfortable using the app without support, 91% described it as user-friendly and 92% said they would recommend it to other health workers. These findings suggest that the AI-assisted RISE application is a feasible and acceptable tool for supporting healthcare workers' self-care and emotional wellbeing in post-conflict settings, although its long-term value depends on integration with trauma-informed health system practices and leadership commitment to a holistic approach to staff wellbeing.

Keywords: *AI-assisted tool; Healthcare workers; Self-care; Emotional wellbeing; Post-conflict setting*

Artificial Intelligence as a Digital Health Strategy for Quality Improvement in Medical Laboratory Services: Review

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Abstract
Medical laboratories influence most clinical decisions, yet increasing workloads, workforce shortages, and complex diagnostic technologies challenge service quality, safety, and efficiency, particularly in resource-limited settings. Artificial intelligence (AI) has emerged as a promising digital health strategy to optimize laboratory processes and strengthen quality management. This review synthesizes current evidence on AI applications that enhance quality improvement across the pre-analytical, analytical, and post-analytical phases of the total testing process. Literature from PubMed, Google Scholar, and laboratory medicine and health informatics journals was narratively synthesized. Evidence indicates that AI supports specimen management, automated result verification, image-based diagnostics, predictive equipment maintenance, and real-time monitoring of quality indicators. These tools reduce errors, shorten turnaround time, and improve analytical precision while enabling risk-based decision-making aligned with ISO 15189 standards. Implementation barriers include poor data quality, limited interoperability, infrastructure gaps, explainability concerns, and workforce readiness. Overall, AI represents a practical and scalable approach to strengthen laboratory quality and patient safety. Sustainable adoption requires investment in governance, training, and digital infrastructure, particularly in low- and middle-income countries.

Keywords: *artificial intelligence, laboratory medicine, quality improvement, digital health, diagnostics, health informatics*

TRACK : AI AND DATA ANALYTICS FOR CYBERSECURITY

Artificial Intelligence and Cybersecurity Integration to Enhance National Interest and Economic Stability through Collaborative Policies

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Abstract

This study investigates the critical intersection of cybersecurity and Artificial Intelligence (AI), analyzing how AI technologies reshape cybersecurity practices while introducing new vulnerabilities. A systematic literature review of 53 primary studies, selected from 2,758 records (IEEE Xplore, ScienceDirect, 2016–February 2025), reveals that AI enhances threat detection accuracy (94–99%) and operational efficiency. However, challenges persist: 2.8 million unfilled cybersecurity positions globally, adversarial AI threats, and ethical dilemmas. The study assesses economic impacts across USA, EU, China, UAE, and Africa, with focus on Ethiopia's Digital Ethiopia 2025 strategy. Policy implications, Zero Trust architecture, and SOAR automation frameworks are examined. Strategic recommendations address digital resilience, skills gap bridging, and coordinated national efforts.

Keywords: *Cybersecurity; Artificial Intelligence; Machine learning; Deep learning; National security; Policy; Ethiopia; Digital transformation*

Blacksmith AI: A Multi-Agent System for Autonomous Vulnerability Assessment and Penetration Testing

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Abstract
The increasing digitization of critical infrastructure across Africa—from financial systems to e-governance platforms—has created an urgent need for scalable, continuous security assessment methodologies. Traditional penetration testing remains resource-intensive, episodic, and inaccessible to many organizations with limited cybersecurity budgets. This paper introduces Blacksmith AI, an open-source, AI-powered penetration testing framework that leverages a hierarchical multi-agent system to automate the complete security assessment lifecycle. The framework consists of five specialized agents:—Reconnaissance, Scanning/Enumeration, Vulnerability Analysis,Exploitation, and Post-Exploitation —coordinated by an Orchestrator agent that managesmission planning and report generation. Blacksmith AI operates within a controlled Docker environment containing 30+ industry-standard security tools, supports multiple Large Language Model (LLM) providers, including OpenRouter and local VLLM deployments, and offers both CLI and web-based interfaces. This paper presents the system architecture, agent workflows, tool integration methodology, preliminary validation results, and a workingdemonstration of automated vulnerability discovery across test environments. Blacksmith AI represents a significant step toward democratizing security assessments for African digital ecosystems, enabling continuous monitoring, educational applications, and research capabilities with minimal human intervention.

Keywords: *Multi-agent systems; Automatedpenetration testing; Vulnerability assessment; AI-powered security; Cybersecurity automation; African digital infrastructure*

Infrastructure Bias in LLM Tokenization

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Abstract

Tokenization disparities represent a critical barrier to equitable artificial intelligence access across linguistically diverse populations. This study presents a comprehensive cross-linguistic evaluation of tokenization efficiency across 200+ languages to quantify computational inequities in large language models. Using a standardized experimental framework, we implemented systematic preprocessing and normalization protocols, followed by uniform tokenization via tiktoken across all language samples. Our methodology incorporated comprehensive tokenization statistics extraction through established evaluation metrics, including Tokens Per Sentence (TPS) measurements and Relative Tokenization Cost (RTC) calculations benchmarked against English baselines. Cross-linguistic efficiency analysis reveals significant systematic disparities. Latin-script languages consistently demonstrate superior tokenization efficiency compared to non-Latin scripts, with variations directly attributable to morphological complexity, orthographic density, and vocabulary structural properties. Aggregate efficiency comparison through RTC metrics demonstrates token inflation ratios reaching 3-5x for morphologically rich and non-Latin script languages, resulting in substantially increased computational demands and reduced effective context utilization. These findings underscore critical inequities in current AI systems, where speakers of underrepresented languages face disproportionate computational barriers. Current research directions emphasize developing language aware tokenization strategies and adaptive vocabulary construction methods to address these disparities. Future investigations should prioritize multilingual tokenizer architectures incorporating linguistic typology considerations and efficiency-preserving sub-word segmentation algorithms to ensure more inclusive and computationally equitable AI system deployment across diverse linguistic communities globally.

Keywords: *LLM; Tokenization; Infrastructure bias; Sub-word system; Multilingual Model*

Tigrigna Emotion Analysis Model for Facebook Comments on Political Posts in Low-Resource Contexts

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Abstract
Emotion analysis in low-resource and morphologically rich languages remains challenging due to the scarcity of annotated data and language-specific processing tools. In this paper, we present the first study on emotion classification for Tigrigna political discourse using Facebook comments. We construct a manually annotated dataset of 1,100 comments based on Ekman's emotion categories and develop a custom Sentence Piece tokenizer to address the morphological complexity of the language. We fine-tune multilingual pretrained models, mBERT and XLM-RoBERTa, using Low-Rank Adaptation (LoRA) to enable efficient training under limited computational resources. Experimental results with 5-fold cross-validation show that XLM-RoBERTa outperforms mBERT, achieving a best Macro F1-score of 0.82. To support future research in low-resource NLP, we publicly release the dataset, tokenizer, and trained models. Our findings demonstrate that combining tailored tokenization with parameter-efficient fine-tuning significantly improves emotion analysis for Tigrigna and similar morphologically rich languages.

Keywords: *Tigrigna NLP; Emotion analysis; Low-resource languages; XLM-RoBERTa; Social media mining*

Handwriting recognition for Tigrigna Geez script language using deep learning with Explainable AI based on Grad-CAM

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Abstract

Handwriting recognition is a branch of pattern recognition and computer vision that has the purpose of converting handwriting into a digital, machine-readable format. This study focuses on Tigrigna, a Geez script language that is particularly suited for low-resource languages and is implemented using deep learning techniques. The dataset was collected from Adigrat University students, encompassing different batches, and the handwritten data was scanned to convert it into digital images. The digital images were pre-processed by converting them into grayscale, removing noise, binarizing, normalizing contrast, normalizing size, and applying augmentation to enhance image quality and increase dataset diversity. The dataset was split into 80% for training, 10% for validation, and 10% for testing using a stratified sampling mechanism. The model was trained using DenseNet-121 transfer learning convolutional neural network. The experiment showed 97.1% accuracy using the unseen 10% dataset, which is promising for low-resource languages like Tigrigna. To make the handwriting recognition more interpretable, the researchers implemented Grad-CAM, Explainable artificial intelligence technique. The visualization results confirmed that the model focuses on key stroke structures of the characters during classification. Ultimately, the research recommends increasing the dataset size and making it more diverse by including a lower-grade handwriting dataset and implementing this on a mobile application.

Keywords: *Handwriting recognition; Geez script language; Optical character recognition; DenseNet-121; Image pre-processing; Character classification; Grad-CAM.*

The Digital Afropolitan: Examining Ali Mazrui's Afropolitanism in the Age of Generative Artificial Intelligence

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Abstract
The rapid diffusion of generative artificial intelligence (AI) technologies is reshaping knowledge production, creativity, and academic practice globally. For African academics and students, these technologies present unprecedented opportunities and major risks. While generative AI tools offer expanded access to knowledge and academic resources, they are largely trained on datasets dominated by Global North languages, perspectives, and epistemologies. Consequently, their use may reproduce forms of epistemic dependency identified in African intellectual traditions. This paper develops the concept of the Digital Afropolitan as a framework for understanding African engagement with generative AI. Drawing on the work of Ali Mazrui and the theory of Africa's "triple heritage," the paper argues that African academics must navigate globalization in ways that combine digital participation with epistemic grounding in African knowledge traditions. Drawing on a conceptual and critical theoretical analysis, the study engages scholarship in decolonial theory, critical AI studies, and African higher education. The paper proposes that the Digital Afropolitan must be characterized by three orientations, which are critical literacy, creative appropriation, and epistemic grounding. These orientations enable African academics to engage generative AI technologies critically while transforming them into tools for intellectual autonomy and knowledge production rather than instruments of cultural dependency. The paper concludes by outlining implications for curriculum reform, research practice, and policy development in African universities.

Keywords: *Afropolitanism; Generative artificial intelligence; African higher education; Cultural dependency; Decolonial theory; Epistemic freedom*

Deep Learning for Amharic Image Captioning: Enhancing Ethiopian Cultural Heritage Accessibility with Optimized Models

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Abstract

Visual comprehension in Artificial Intelligence (AI) enables machines to describe images in natural language. However, image captioning research has largely overlooked low-resource languages such as Amharic due to limited domain-specific datasets and linguistic complexity. To address these gaps, this study developed a deep learning-based Amharic image captioning model focused on Ethiopian cultural heritage to promote cultural preservation. A dataset of 4,258 cultural heritage images, each annotated with five expert-verified Amharic captions (21,290 captions in total), compiled from reputable sources, including UNESCO's World Heritage List, Awaze Tours, and Visit Ethiopia. Text preprocessing handled Amharic's morphological complexity through tokenization, stop-word removal, character normalization, and abbreviation expansion. The dataset is divided using a 70:15:15 training, validation, and testing split for balanced model evaluation. The proposed model employs a pre-trained ResNet50 encoder with a GRU decoder as the baseline architecture. Performance is compared using attention and Transformer-based variations, evaluated with BLEU, ROUGE, METEOR, and CIDEr metrics. The ResNet50–GRU baseline with beam search (beam width = 3) achieved the best overall balance between accuracy and efficiency (BLEU-1: 0.5096, BLEU-4: 0.1196, METEOR: 0.2093, CIDEr: 0.2692) among the evaluated models. While the Transformer decoder generated richer captions, its higher computational cost makes the baseline model more suitable for mobile and resource-limited applications. This research demonstrates the potential of deep learning for Amharic image captioning and emphasizes the importance of high-quality datasets and efficient architectures for low-resource languages and cultural heritage preservation.

Keywords: *Amharic image captioning; Ethiopian cultural heritage; Deep learning; Transformer; Computer Vision; Natural Language Processing*

Deep Learning-based Amharic Chatbot for FAQs in Universities

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Abstract
University students often spend a considerable amount of time seeking answers to common questions from administrators or teachers. This can become tedious for both parties, leading to a need for a solution. In response, this paper proposes a chatbot model that utilizes natural language processing and deep learning techniques to answer frequently asked questions (FAQs) in the Amharic language. Chatbots are computer programs that simulate human conversation through the use of artificial intelligence (AI), acting as a virtual assistant to handle questions and other tasks. The proposed chatbot program employs tokenization, normalization, stop word removal, and stemming to analyze and categorize Amharic input sentences. Three machine learning model algorithms were used to classify tokens and retrieve appropriate responses: Support Vector Machine (SVM), Multinomial Na¨ıve Bayes, and deep neural networks implemented through TensorFlow, Keras, and NLTK. The deep learning model achieved the best results with 91.55% accuracy and a validation loss of 0.3548 using an Adam optimizer and SoftMax activation function. The chatbot model was integrated with Facebook Messenger and deployed on a Heroku server for 24-hour accessibility. The experimental results demonstrate that the chatbot framework achieved its objectives and effectively addressed challenges such as Amharic Fidel variation, morphological variation, and lexical gaps. Future research could explore the integration of Amharic WordNet to narrow the lexical gap and support more complex questions.

Keywords: *Amharic; Chatbot; Deep learning; Natural language processing; Support vector machine; Tokenization*

Systematic Evaluation of Automatic Speech Recognition Systems for Tigrinya: Quantifying Performance Disparities Across Dialects, Demographics, and Acoustic Conditions

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Abstract
Automatic Speech Recognition (ASR) systems for low-resource languages demonstrate substantial performance variation across demographic groups and linguistic varieties. We tested Meta MMS-1B, Badrex W2V-BERT 2.0, Samuael ASR, and Meta Omni-lingual CTC-1B on 1,000 recordings across seven condition types for Tigrinya, an Ethiopian Semitic language using the Ge'ez script. We measured performance using WER, CER, and PIER, and applied a character normalization step beforehand to handle redundant Ge'ez characters that would otherwise inflate error scores. Recordings cover gender, three noise levels, Central Tigray and Raya dialects, four speech styles, two utterance length groups, and code-switched speech. Badrex and Omni-lingual performed best on clean speech (WER 0.10–0.18); every model collapsed on Raya dialect recordings (WER 0.87–1.00), producing Central Tigray output rather than silence; and gender gaps went in opposite directions by model — Badrex favouring male speakers, MMS favouring female. On code-switched utterances, every model forced English words into Tigrinya syllable patterns, and PIER ran well above CER, showing that word-boundary breakdown — not just wrong characters — was a major error source. Normalizing the Ge'ez characters cut measured error by 16–19%, large enough that we treat it as a required step. These results show clearly which communities current Tigrinya ASR can and cannot serve.

Keywords: *Automatic speech recognition; Tigrinya, Ethiopian Semitic languages; Ge'ez script; Dialectal variation; Gender bias; Fairness*

A Hierarchical Error Analysis of Tigrigna Text-to-Speech Systems: Comparative Evaluation of facebook/mms-tts-tir and Google Gemini TTS

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Abstract

Performing an error analysis on text-to-speech model helps to identify key limitations, making it easier to design a strategy for fine-tuning the model to a specific target language or dialect. This paper provides a systematic comparison and diagnostic evaluation of two publicly accessible Tigrigna TTS endpoints: facebook/mms-tts-tir, a multilingual end-to-end text-to-speech model, and Google Gemini TTS, a large language model (LLM)-based synthesis system. The evaluation used a custom dataset of 235 test sentences taken from grade 6 social science and grade 7 biology textbooks. This dataset was designed to ensure balanced phonetic coverage of the Tigrigna syllabary. A three-tier hierarchical annotation scheme was applied in Praat to assess synthesis quality at the character, word, and sentence levels. Google Gemini TTS significantly outperformed facebook/mms-tts-tir in almost all measurements, with a character error rate (CER) of 3.50% compared to 5.74%. Its mean opinion score (MOS) for naturalness was also higher at 4.69 versus 3.46. Both systems show a failure in gemination. The main challenge for facebook/mms-tts-tir is the Uroman grapheme-to-phoneme (G2P) front-end. Uroman causes phonetic collapse and phoneme-boundary ambiguity within a word. Furthermore, aggressive punctuation removal during the text normalization destroys prosodic structure of the sentence. For Google Gemini TTS, a dialect drift and Amharic phonetic interference indicate insufficient diversity and cleanliness in its training corpus. The taxonomy and mitigation strategies presented here provide a roadmap for improving Uroman-based G2P pre-processing and reducing the 11.98% under-gemination rate documented here.

Keywords: *Comparative evaluation; Error taxonomy; TTS; Tigrigna; Error Analysis.*

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