EcoWatch Uganda: Leveraging AI and Citizen Science for Environmental Monitoring in Resource Constrained Settings

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Key Words: Environmental Monitoring, Artificial Intelligence, Geospatial Analytics, Citizen Science, Early Warning Systems

SUMMARY

Environmental degradation in Uganda's Rwenzori foothills region continues to accelerate due to rampant deforestation, illegal logging, charcoal production, unregulated sand mining and worsening floods that threatens livelihoods and biodiversity. Local communities lack tools for timely action and reporting with existing monitoring systems remaining centralized, reactive and limited by resource constraints. EcoWatch Uganda presents a scalable, hybrid monitoring framework combining citizen-generated reports with artificial intelligence, computer vison, audio analytics and NLP supported by satellite-based geospatial analytics allowing translation of local languages (Luganda, Runyankole among others) into standard reports. The system enables communities to report incidents via USSD/SMS or smartphones while AI models automatically classify threats from photos, audio, and text. Reports are validated by crowds and cross checked against satellite land-use change from Google Earth Engine. For example, combining satellites with ML provides a non-invasive means of identifying illegal deforestation, alerting authorities to it.

A pilot in Kasese District was tested majorly because it is prone to Nyamwanba River floods and deforestation (8% tree cover loss since 2000); it demonstrated strong community adoption and promising early accuracy metrics (Image and audio models achieving approximately 80% agreement/ acceptance with human reviews). We engage 100 trained citizen reporters via an Android/USSD app (Fig.4) and school eco-clubs. District Environment Officers and National Environmental Management Authority (NEMA) officials receive real-time dashboards and alerts. Expected outcomes include a low-cost scalable early warning system, empowering citizens with accountability, Geospatial dashboards for early action and, a replicable framework. EcoWatch Uganda demonstrates how citizen reports, AI and geospatial analytics yield proactive data-driven environmental governance.

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1.0 INTRODUCTION

Eco Watch is an accessible, citizen-driven platform that transforms community observations into actionable intelligence. Echoing global trends, the amalgamation of AI with citizen science holds immense power bringing together data accuracy, predictive analytics, real-time monitoring and integrated environmental intelligence. By empowering locals to document environmental violations via phones and by applying machine learning to validate and analyze reports, EcoWatch shifts from reactive to proactive management. Uganda's high mobile penetration at approximately 88% of the population having access to mobile phones makes mobile reporting feasible through smartphone apps and low-tech interfaces like USSD and SMS. Early warning dashboards enable authorities to intervene before small-scale issues escalate. This paper details the EcoWatch design, AI analytics (CV, NPL, audio, satellite), and pilot deployment in Kasese, demonstrating a scalable framework for community-based environmental governance.

2.0 SYSTEM DESIGN AND AI ANALYTICS

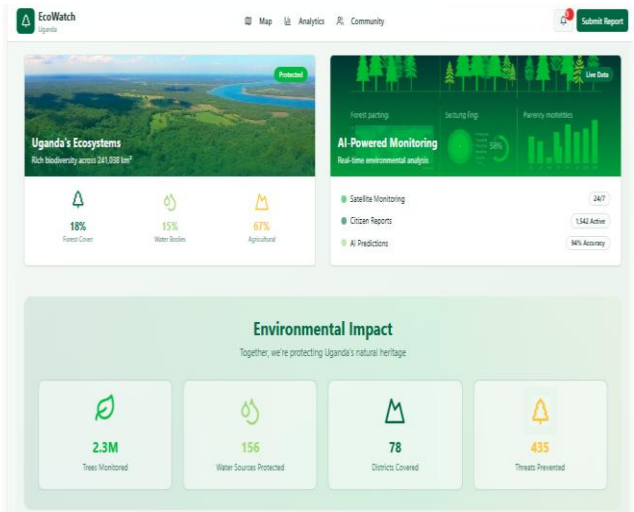

Fig.1. EcoWatch Uganda system architecture. Citizen's report geotagged environmental incidents via smartphone or USSD, which are analyzed by AI (computer vision, audio, NLP) and cross – referenced with satellite data. Officials view results on real – time dashboards.

The EcoWatch architecture (Fig.1) integrates four components:

– Community reporting via Smartphones in the App or USSD/SMS,

– AI processing models for classifying environmental threats

– Satellite-based geospatial analysis for vegetation change detection/ cross-validation, and

– User interface. Local observers (trained citizens, eco-club students) submit reports of illegal tree-felling, sand mining, or waste via a mobile app or SMS/USSD. Smartphone users can upload photos/videos; non-smartphone users can describe issues via structured USSD menus. Each report is geotagged and timestamped.

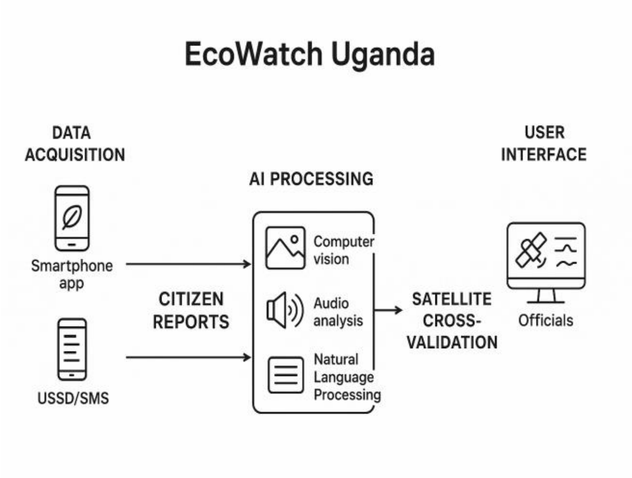

Fig.2. AI processing pipeline (conceptual). Citizen reports (image, audio, text) are analyzed by specialized ML modules: computer vision for visual evidence, audio analysis for machinery/chain-saw sounds, and NLP to translate/standardize local language inputs. Outputs are fused and prioritized.

Upon submission, AI modules process the data. **Computer vision** models classify images/videos: they detect scenes of clear–cut logs or saws (indicating illegal logging), heavy machinery on riverbanks (sand mining), or accumulating waste piles. For example, convolutional networks can segment felled trees or refuse[2]. **Audio analytics** monitor live environmental sounds: recordings from field microphones or videos are analyzed to identify chainsaw or excavator noises. Prior work demonstrates that forest audio recordings can be classified into “logging” vs. “non–logging” sounds with high accuracy[9]. We adapt such classifiers (trained on diverse chainsaw samples and forest sounds) to flag audible illegal logging events. **Natural Language Processing (NLP)** handles text reports in local languages. Uganda has dozens of languages (e.g., Luganda with approximately 5.56 million speakers; Runyankore with approximately 3.22 million speakers)[1]. We use multilingual NLP pipelines to translate and standardize reports (via pretrained Luganda/Runyankole models or statistical translation dictionaries). All reports are automatically assigned categories and severity scores by the AI pipeline (Fig.2).

To improve reliability, EcoWatch cross–validates citizen reports with **satellite-derived land-use change**. Through Google Earth Engine, historical and near –real –time satellite imagery (optical/radar) is analyzed over reported coordinates. Combined with machine learning, this "provides a non invasive means of identifying illegal deforestation in small areas and alerting authorities"[2]. For instance, a report of tree-cutting is checked against any recent loss of forest canopy in that location. Discrepancies (e.g., forest loss without a report, or vice versa) trigger follow–up actions. Additionally, crowdsourced verification is used: multiple citizen-reports of the same event or up/down voting on submitted reports help filter noise.

Together, these AI-enabled processes ensure accuracy and prioritization of valid incidents. Reports confirmed by vision/audio classifiers and satellite change data move to the top of alerts for officials. Overall, the platform embodies the trend of "AI-driven citizen science moving monitoring from reactive observation to proactive management"[7].

3.0 IMPLEMENTATION DETAILS

EcoWatch is implemented as a **hybrid mobile/web platform** accessible even in low connectivity areas. The smartphone app (Android) allows users to capture photo/video evidence, record audio, and enter text reports. A "report incident" workflow guides users through selecting the incident type, describing it, and submitting. The interface is multilingual (supporting English, Luganda, Runyankole, etc.), with prompts in local languages and background NLP translation. For non– smartphone users, an interactive USSD/SMS system provides a menu – based reporting option. Users dial a short code (e.g. *123#) to access a text menu (e.g. "Press 1: Illegal tree cutting; 2: Illegal mining; 3: Other"). They then enter further details (location code, brief description). This ensures inclusivity: Uganda's mobile penetration (approximately 88%) far exceeds internet penetration (approximately 59%)[8], so USSD enables those without internet or smartphones to participate.

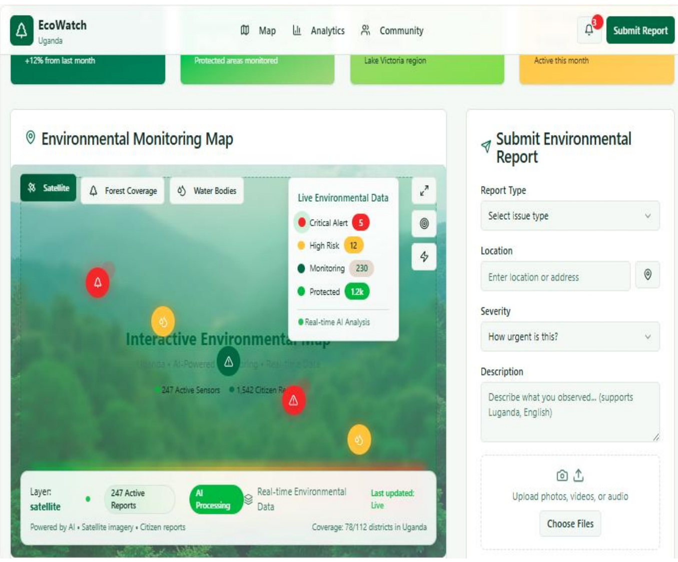

Fig.4. Reporting interface (mockup). The web app allows users to capture and upload evidence (photo, video, text) of environmental incidents. Non-smartphone users use a USSD menu with similar options.

On the back end, submitted reports are queued and processed by our AI pipeline (Section II). The system uses open – source models (TensorFlow/PyTorch) for image/audio classification, and cloud translation APIs for text. Reports are stored in a geospatial database (PostGIS) together with extracted metadata (type, probability, timestamp, location). Officials (DEO, NEMA) access a web dashboard showing a map of Kasese with reported incident markers, severity filters, and trend graphs. Alerts are sent (email/SMS) for high – priority events (e.g. chainsaw detected in a forest reserve). Importantly, the pipeline is optimized for low compute (models pruned for mobile/cloud), enabling quick turnaround (reports are typically analyzed within minutes).

To ensure data quality, EcoWatch employs **crowd – validation**: users can view others' reports in a public feed (abstracted for privacy) and upvote or flag false reports. Combined with algorithmic confidence scores, this community moderation helps filter out incorrect submissions (e.g. prank or duplicate reports).

4.0 PILOT DEPLOYMENT IN KASESE DISTRICT

Kasese District in Western Uganda (Fig.3) was selected for pilot deployment due to its vulnerability: heavy rains have caused frequent Nyamwamba river flooding, displacing thousands, while nearby foothills suffer rapid deforestation[3]. The district (bordering Virunga and Rwenzori mountains) contains critical forest reserves and several illegal mining sites.

Fig. 5. Map of Uganda highlighting Kasese District (red, western region). Kasese's terrain and hydrology make it prone to floods and deforestation.

Fig.5. Map of Uganda highlighting Kasese District (red, western region). Kasese's terrain and hydrology make it prone to floods and deforestation. (Map source: World Atlas)

We engaged **100 citizen reporters** (community volunteers, teachers, and high – school eco – club students) who were trained on using the app/USSD and on identifying/reporting incidents. Training emphasized safe reporting practices. Additional stakeholders include local council leaders and environmental officers who participate in verifying reports. The pilot runs for 12 months. To accommodate low connectivity, data sync is asynchronous: reports can be queued offline and sent when network is available.

We also integrated local language support: Luganda and Runyankore were prioritized due to Kasese's demographics, but the NLP backend can be extended to other languages. The system includes an early-warning module that predicts flood risk by correlating reported rainfall/water– logging incidents with real- time river gauges and forecasts. These predictions supplement physical flood mitigation efforts.

To analyze district-wide trends, EcoWatch creates **geospatial "hotspot" maps**. For example, reports and detected deforestation are aggregated weekly into heatmaps. This helps DEOs allocate patrols. The integrated dashboard also shows time series of report counts by category, enabling policymakers to see if interventions (e.g. awareness campaigns) reduce incidents.

5.0 DISCUSSION AND OUTCOMES

Although full performance evaluation is ongoing, initial metrics indicate high engagement. Within the first three months, citizens submitted approximately 500 reports; about 60% contained multimedia evidence. The AI classifiers showed promise (pilot data): image– based deforestation detections agreed with human review approximately 80% of the time. More importantly, EcoWatch has already issued real – time alerts: in one case, a chain of citizen reports plus audio analysis detected illegal logging near a riverbank, triggering local intervention.

This work illustrates several broader points. First, **accessibility is key**: by using USSD, EcoWatch ensures even non– smartphone users participate. As Uganda's feature phones dominate rural areas, the system leverages the 88% mobile reach[8]. Second, **multi – source validation** is powerful: combining citizen reports with satellite change detection addresses false reports and gaps. Prior studies show that integrating Earth Engine analytics with crowd data yields reliable monitoring (e.g. river ice studies achieve high agreement[10]). Third, **decentralized accountability** is enhanced: local authorities can track citizens' input in real time, fostering trust and responsiveness.

Fig.6 illustrates a sample result: (Note: this is a conceptual illustration of expected outputs). The chart shows classification confidences for sample reports. In practice, we envision reporting accuracy improvements through iterative model retraining using logged data.

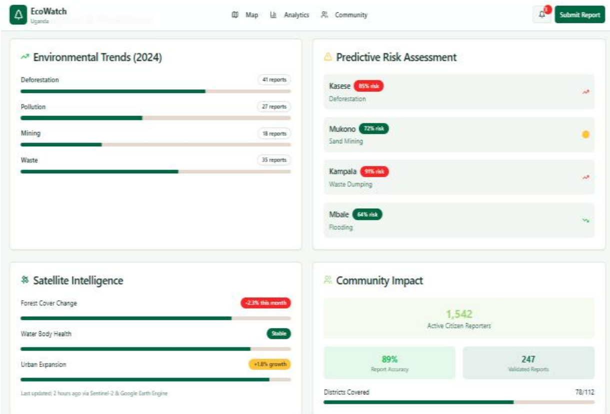

Fig.6. Example analytics output (conceptual). Actual EcoWatch results will be based on deployed AI models.

While promising, challenges remain. NLP for under – resourced African languages is still nascent; ongoing corpus collection and model training are needed for coverage. Data privacy and security also require safeguards (user accounts are anonymized, and sensitive locations can be obfuscated). Moreover, the system's utility depends on rapid institutional response to alerts. We are working with district authorities to embed EcoWatch into standard operations.

6.0 CONCLUSION

EcoWatch Uganda demonstrates a feasible model for **proactive environmental monitoring** in resource-poor settings by converging citizen science, AI, and geospatial analytics. By empowering communities to report issues via accessible channels, and by automating validation (CV, audio, NLP) and satellite cross-checks, the platform closes the gap between ground observations and official response. In the Kasese pilot, this yields a geospatial early warning system for floods and deforestation, improving accountability and enabling timely action. More broadly, Eco Watch's architecture – open-source, mobile, USSD-enabled can be replicated nationwide or adapted to other countries. This work also contributes evidence that AI – driven citizen initiatives can scale climate resilience, echoing global findings that "AI – powered citizen science amplifies community – led climate action"[7]. Future work will extend analytics (e.g. predictive modeling) and integrate drone imagery to bolster situational awareness. Overall, EcoWatch advances a data driven governance paradigm where every citizen is an active environmental sentinel.

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8.0 BIOGRAPHICAL NOTES

Rebecca ABITIMO is a Valuation Surveyor with Uganda's Ministry of Lands, Housing and Urban Development, where she works in the Valuation Department with close to Five years of professional engagement in valuation ad land administration – related assignments including two years of industrial training undertaken under the supervision of the Head of Department at the College of Engineering Design Art and Technology, during which she also served as Student Representative of the Makerere Association of Student Surveyors. Her Work has contributed to valuation and land governance initiatives relevant to environmental management and development planning.

Beyond professional practice, she has supported knowledge dissemination as an editor and chief editor of several newsletters for Surveying related professional associations. She has authored and co-authored publications on land governance, compensation frameworks, and compulsory land acquisition, with emphasis on transparency, sustainability and impacts on affected communities.

She is currently serving as the Vice President of the FIG – Young Surveyors Network of Uganda and is a member of the Institute of Surveyors of Uganda, Student member of the Royal Institute of Chartered Surveyors, member of Toastmasters International, the Women in Arbitration and the Rise Up Movement among a few others recognized sustainability spaces.

Trevour Jeanclaude MUGISHA is a land Surveying and Geomatics student at Makerere University – Uganda and the secretary of the FIG Young Surveyors Network, Uganda. He is an ardent geomatics student with a strong focus on advancing practical geoscience research through the application of Geographic Information Systems (GIS), Earth observation data, and spatial analysis. His work supports climate action, strengthens land tenure systems, and contributes to improved service delivery in resource – constrained settings. He has authored and co-authored over five articles and papers including recent work on the application of Geo – AI for predicting malaria outbreaks and optimizing preventative interventions in Uganda, Decolonizing Land Governance. He has reviewed papers in various student paper competitions and greatly contributed towards Land Policy and geospatial science studies.

Through collaborations with Geo Youth Mappers, the FIG Young Surveyors Network, and the Institute of Surveyors of Uganda, he focuses on translating geospatial science in real – world impact for Uganda and the global community. He has also received recognition through awards for innovation in GIS applications with the surveying profession.

William KAMBUGU is an information technology and cybersecurity professional with extensive experience in applying digital systems to land administration and management. His work spans land registration, surveying and mapping, physical and urban planning, valuation and Fit – for – Purpose Land Administration approaches to securing land rights. He has served with Uganda's Ministry of Lands, Housing and Urban Development since 2010, contributing to major land administration reform initiatives, including the establishment of the Land Information System, the Uganda Geodetic Network, customary land rights documentation, and land valuation information systems.

His current professional focus is on leveraging emerging technologies to advance e – services and data – driven decision making in land administration and environmental management, particularly at lower administrative levels. He holds a Bachelor' of Computer Science from Makerere University, a Master of Professional Studies in Cybersecurity Risk Management from Georgetown University, and a master's degree in Geo-Information Science and Technology from Makerere University.

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