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Environmental Impact Assessment of Mobile Campaign Apps: Insights from the Red Rose One App in Nigeria

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Abstract — The proliferation of mobile applications in Information and Communication Technology for Development (ICT4D) has delivered critical social and health benefits across low-resource settings. However, these digital solutions often impose hidden environmental costs including high energy consumption, accelerated device obsolescence, and electronic waste that undermine their long-term sustainability and equity. This paper introduces and empirically validates the Environmental Mobile App Impact Assessment (EMAIA), a novel framework designed to measure and mitigate the sustainability impacts of ICT4D (Information and Communication Technology for Development) applications. Through a comprehensive case study of Nigeria's RedRose One app used by 128 frontline health workers in Seasonal Malaria Chemoprevention campaigns we demonstrate EMAIA's practical utility across five key dimensions: Energy Consumption, Device Lifecycle, Network Utilization, E-Waste Contribution, and Carbon Emissions. Survey results reveal a significant environmental and user burden: 77.3% of workers report excessive battery drain, 60.2% were compelled to upgrade devices specifically for app compatibility, 70.3% face high data costs, and 49.2% have disposed of devices due to compatibility issues. These indicators culminate in a poor overall EMAIA score of 1.90/5.00, highlighting a critical disconnect between the app's public health objective and its unsustainable operational footprint. Qualitative analysis of open-ended responses further underscores user priorities, with 62% of suggestions advocating for robust offline functionality and 41% requesting broader compatibility with older and low-specification devices. The study establishes that environmental sustainability in ICT4D is not a peripheral concern but is intrinsically linked to equity, accessibility, and long-term viability. By making environmental impacts measurable and actionable, the EMAIA framework provides developers, practitioners, and policymakers with an essential tool to align digital innovation with the Sustainable Development Goals. We argue for the mandatory integration of such assessments into the ICT4D project lifecycle to ensure that technological progress delivers social benefits without imposing ecological costs or financial burdens on the communities it aims to serve.

Keywords— Environmental Impact Assessment (EIA), Mobile Campaign, Applications, Red Rose One App, Nigeria, Green Information Technology (Green IT), Sustainable Mobile Computing, Digital Sustainability, Carbon Footprint, Energy Consumption.

I. INTRODUCTION

The proliferation of mobile technology has ushered in a transformative era for global health and development. Smartphones and tablets are now pivotal tools for data collection, community health worker support, supply chain logistics, and service delivery in low-resource settings, a domain broadly termed Information and Communication Technology for Development (ICT4D (World Health Organisation, 2017). These digital tools are celebrated for enhancing operational efficiency, program accountability, and the scale of public health interventions (Braa et al., 2004). Yet, this rapid digitization carries an under-examined cost. The prevailing discourse in ICT4D has predominantly highlighted socioeconomic "digital dividends," while largely neglecting the environmental externalities of these solutions (Mustafa et al., 2024). The environmental footprint of a mobile application, encompassing its energy consumption, data transmission requirements, and hardware dependencies; directly impacts its feasibility and equity in resource-constrained contexts. For instance, high energy use drains batteries where charging is inconsistent; substantial data consumption inflates costs for users; and poor compatibility with older devices can accelerate electronic waste (e-waste) and impose financial burdens (Ankit et al., 2021). This creates a paradox where tools designed for social good may inadvertently exacerbate the digital divide and contribute to environmental degradation, issues that disproportionately affect communities in the Global South (Anzum et al., 2026).

Despite the clear intersection of environmental sustainability and development equity, a significant methodological gap persists. Existing evaluation frameworks for ICT4D projects, such as those focusing on user adoption or health outcomes, lack standardized metrics to assess environmental performance (Goswami et al., 2023). Life Cycle Assessment (LCA) methodologies exist but are often too complex and data-intensive for practical application in typical ICT4D project cycles (Wang et al., 2023).

To bridge this gap, this paper introduces and empirically validates the Environmental Mobile App Impact Assessment (EMAIA) framework. EMAIA offers a pragmatic, multi-dimensional tool to evaluate the sustainability of mobile applications across five key areas: Energy Consumption, Device Lifecycle, Network Utilization, E-Waste Contribution, and Carbon Emissions. We test this framework through a mixed-methods case study of the RedRose One application, a mobile platform deployed for Seasonal Malaria Chemoprevention (SMC) campaigns in Nigeria. By analyzing survey data from 128 frontline health workers, we demonstrate EMAIA's utility in quantifying environmental impacts and translating user experiences into actionable design insights.

This research argues that environmental sustainability must be a core criterion not an afterthought in the design and evaluation of ICT4D initiatives. By providing a structured assessment tool, we aim to align digital development practices with broader Sustainable Development Goals (SDGs), ensuring that technological progress does not come at the cost of ecological integrity or user equity.

II. LITERATURE REVIEW

Information and Communication Technology for Development (ICT4D) has evolved significantly, moving from a focus on technology provision to a more nuanced understanding of socio-technical integration (World Health Organisation, 2017). Mobile phones, in particular, have become the primary platform for development interventions in areas like healthcare (mHealth), agriculture, finance, and education. Success stories often highlight improved data collection efficiency (Holtey, 2019), enhanced community health worker (CHW) performance (Coertjens et al., 2021), and greater financial inclusion (Nunn et al., 2008). However, a persistent critical discourse has cataloged frequent failures, attributing them to a "design-reality gap," lack of contextual fit, and unsustainable financial models (Central Bank of Nigeria, 2018). On the other hand, unreliable electricity still limits how health workers can use mobile apps in the field. Research in rural Kenya found that charging a phone could be a significant logistical and financial hurdle, directly affecting how an mHealth app was used (Villagrán-Zaccardi et al., 2022). Until recently, "sustainability" within ICT4D was primarily discussed in terms of financial viability and institutional ownership post-funding. The environmental dimension of sustainability has been largely absent from mainstream ICT4D literature and evaluation frameworks. This omission is significant, as noted by Wyche and Murphy (2012), who highlighted that the material realities of technology battery life, charging costs, and device durability directly impact adoption and equity in off-grid communities. The field has thus developed a form of environmental amnesia, prioritizing digital access without accounting for its ecological footprint. Parallel to ICT4D, the broader fields of Human-Computer Interaction (HCI) and Sustainable Computing have developed a robust literature on the environmental impacts of digital technology. Concepts like "Frugal Innovation" (Sharif et al., 2024) and "Design for the Global South" (Deku et al., 2024) have long argued for low-cost, resource-light, and locally appropriate technology. More recently, this has evolved into the "Green Software" movement, which focuses on writing energy-efficient code, optimizing data center operations, and considering carbon-aware computing (Tolulope Ogundipe et al., 2024). Research in HCI has critically examined the sociotechnical implications of e-waste, documenting how the rapid turnover of devices in the Global North creates secondary markets and disposal challenges in the Global South (Meena et al., 2023). Studies have also quantified the carbon footprint of digital services, from streaming video to cloud computing (Jain et al., 2023). However, this body of work has rarely been applied systematically to the specific context of bespoke, project-based mobile applications in development sectors. Recent studies have reinforced that energy access remains a fundamental barrier. Wiese et al. (2023) found that unreliable electricity and high costs of mobile charging in rural Kenya directly limited the effectiveness of a maternal health app for CHWs. This aligns with earlier work by Regasa et al. (2026), emphasizing that the "last mile" of connectivity is often dependent on the "last watt" of power. The cost of mobile data is a recurrent theme. Research by Abebe et al. (2021) on agricultural apps in Ethiopia demonstrated how data expenses can be a prohibitive factor for smallholder farmers, potentially widening inequality (Regasa & Lishan, 2026). This connects to broader critiques of the "datafication" of development, where the benefits of data collection are not always balanced against the costs incurred by users (Taylor & Broeders, 2015). Scholars are beginning to propose integrative models. Tomlinson et al. (2013) introduced "Collapse Informatics," which considers technology design in the context of environmental and societal resource constraints a highly relevant but underutilized lens for ICT4D (Mozelius et al., n.d.). More recently, a 2024 review by Ahmed and colleagues called for a "Green ICT4D" agenda, proposing principles like "offline-first" design, support for low-spec devices, and carbon-aware data hosting (Nascimento & Correia, 2011). Despite this growing awareness, a critical methodological gap persists: there is no widely adopted, standardized framework for assessing the environmental impact of a specific mobile application in an ICT4D context. Life Cycle Assessment (LCA) is a comprehensive environmental management tool (Rahaman et al., 2024), but its application to software is complex, data-intensive, and often focuses on hardware manufacturing rather than in-use operational impacts (Ara, 2022). It is impractical for the rapid evaluation cycles of most development projects.

Green software engineering principles offer guidelines (e.g., energy-efficient coding patterns) but lack an integrated scoring system that combines user experience (e.g., perceived battery drain) with technical metrics (e.g., data packet size) and project-specific concerns (e.g., device accessibility) (Habchi et al., 2017). Existing ICT4D evaluation frameworks, such as the Capability, Approach, Sustainability (CAS) framework or logic models, are silent on environmental indicators (Bitzer & Schouten, 2023).

This review therefore identifies a clear need: a pragmatic, multi-dimensional assessment tool that bridges the conceptual work on Sustainable ICT/Green HCI with the practical realities of ICT4D project management. Such a tool must be usable by developers and evaluators, focus on the key sustainability pain points reported by end-users, and generate actionable insights for improving app design and deployment strategy. This paper aims to fill this gap with the proposed EMAIA framework.

III. METHODOLOGY

1. Methods

This study employed a convergent mixed-methods design (Hu et al., 2023) to develop and validate the Environmental Mobile App Impact Assessment (EMAIA) framework. The research proceeded in two phases: (1) Framework Development, where we operationalized the EMAIA dimensions based on literature and ICT4D practitioner input; and (2) Framework Validation, where we applied EMAIA to a real-world case study using both quantitative survey data and qualitative user feedback.

This approach allowed for methodological triangulation, strengthening the validity of our findings by comparing numerical results with narrative explanations.

The diagram presents a convergent mixed-methods research flow that develops and validates the EMAIA framework by simultaneously collecting quantitative survey data and qualitative user feedback from a case study of 128 health workers, processing this data, applying a weighted five-dimensional assessment (prioritizing network use and device access), and aggregating the results to produce a validated sustainability score and actionable recommendations.

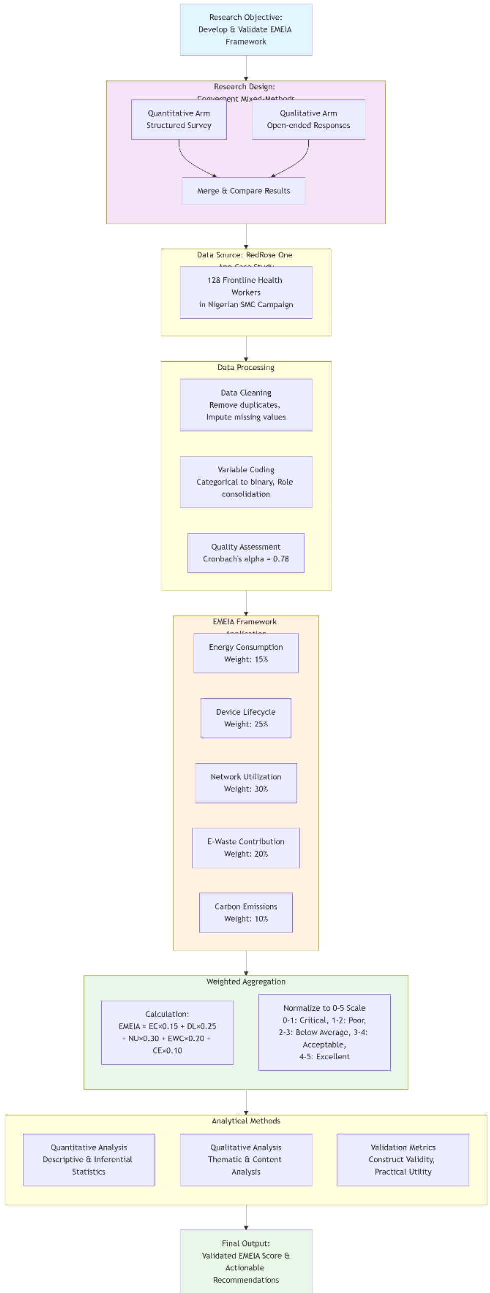

Figure. 1 Framework of the Proposed Method.

2. Data Preprocessing.

To ensure data quality and consistency, the following preprocessing steps were applied: This involved the removal of any entries with clearly test-related emails or placeholder responses being identified and excluded. Responses with identical timestamps and identical patterns across all fields were treated as accidental duplicates; only the first complete entry was retained. For categorical variables, missing responses were coded as "No Response" to maintain transparency. For the energy efficiency rating (a 1-5 scale), three missing values were imputed using the median score of 4.0, as these were isolated omissions in otherwise complete surveys.

3. Variable Coding and Transformation

Categorical Variables (Yes/No) responses were coded as binary (1/0). "Maybe" and "Not Sure" responses were maintained as a separate neutral category to preserve response nuance. The varied "Supervisor" titles (e.g., "Cluster Supervisor," "Health Facility Supervisor" and CDD Supervisor) were aggregated into a single "Supervisor" category for demographic analysis. Responses to "How do you primarily access the app?" (which allowed multiple selections) were parsed into four binary variables: Mobile Data, Wi-Fi, Offline Mode, and Hybrid (any combination). The cleaned dataset showed good internal consistency, with Cronbach's alpha of 0.78 for questions mapping to the EMAIA framework. Response patterns showed logical relationships (e.g., those reporting battery impact generally gave lower energy efficiency ratings), suggesting attentive responding.

4. Dataset Description

The dataset for this research comprised responses collected from end-users of the RedRose One App deployed in mobile mass campaign programs (SMC) across selected states (Gombe and Kano) in Nigeria. A total of 128 valid questionnaires were obtained through an online survey instrument designed around the EMAIA framework. The dataset includes structured variables covering user demographics, patterns of app interaction, perceived battery and mobile data consumption, device performance effects, infrastructure dependency, and environmental awareness indicators. Responses were recorded primarily on a five-point Likert scale, enabling quantitative assessment of sustainability dimensions and subsequent computation of composite environmental impact scores.

5. The EMAIA Framework Structure

The EMAIA framework assesses environmental impact across five dimensions, each containing specific indicators:
Energy Consumption (EC): This measures the direct energy footprint of the app during use. The primary indicators includes:

- User-reported battery impact (Yes/No)
- Use of power-saving features (Yes/No/Not Sure)
- Energy efficiency rating (1-5 Likert scale)

EC Score = (Weighted average of normalized indicators). This is calculated from the data from 128 respondents:

- Battery Impact (Q2): 77.3% said Yes (99 people) → This is BAD for energy efficiency.
- Power-Saving Use (Q3): 28.9% said Yes (37 people) → This is GOOD.
- Energy Rating (Q16): Average = 3.64/5 → This is MODERATE.

Normalizing Each Indicator on a scale of 0-5 Scale. We convert each percentage/average to a 0-5 score where 5 = Best energy efficiency, 0 = Worst.

Score = 5 × (Good Value / Maximum Possible)

Indicator 1: Battery Impact

- 77.3% said YES to battery drain → This means only 22.7% said NO.
- If 100% said NO battery drain = Perfect score (5/5)
- If 100% said YES battery drain = Worst score (0/5)

Score = 5 × (22.7% / 100%) = 5 × 0.227 = 1.14

Indicator 2: Power-Saving Use

- 28.9% use power-saving features → Direct percentage.
- If 100% use features = Perfect (5/5)
- If 0% use features = Worst (0/5)

Score = 5 × (28.9% / 100%) = 5 × 0.289 = 1.45

Indicator 3: Energy Rating

- Average rating = 3.64/5 → Already on 0-5 scale.
- Score = 3.64 (no conversion needed)

Not all three indicators are equally important for measuring energy consumption. We need internal weights, hence we assign:

- Battery Impact: 40% (Most important - direct user experience)
- Power-Saving Use: 30% (Behaviour indicates problem awareness)
- Energy Rating: 30% (Overall perception)

Therefore, final EC Score = $(\text{Score}_1 \times \text{Weight}_1) + (\text{Score}_2 \times \text{Weight}_2) + (\text{Score}_3 \times \text{Weight}_3)$.

EC Score = (1.14 × 0.40) + (1.45 × 0.30) + (3.64 × 0.30)
= (0.456) + (0.435) + (1.092)
= 1.98

Final Score approx. = 2.0

Higher scores indicate better energy efficiency.

Device Lifecycle (DL): This assesses the app compatibility with existing hardware and supports device longevity. The primary indicators include:

- Use of older/refurbished device (Yes/No)
- Performance on older devices (Smooth/Issues/N/A)
- Plan to upgrade for better performance (Yes/No/Maybe)

DL Score = (Positive compatibility factors) - (Negative obsolescence factors). Higher scores indicate better device lifecycle support.

This metric

- Uses Older Device (Q4): 45.3% Yes (58 people) → This is GOOD for supporting device longevity.
- Performance on Old Device (Q6): For the 58 with old devices: 52.9% Smooth (31 people), 47.1% Issues (27 people).
- Plan to Upgrade (Q13): 70.3% Yes (90 people) → This is BAD for device lifecycle.

We convert each percentage to a 0-5 score where 5 = Best device lifecycle support, 0 = Worst.

Indicator 1: Older Device Use (GOOD)

- 45.3% use older/refurbished devices
- This is POSITIVE → The app is accessible to people with limited resources.

Score = 5 × (45.3% / 100%) = 5 × 0.453 = 2.27

Indicator 2: Performance on Old Devices

- 52.9% report smooth performance on old devices
- This comes from: 31 smooth / 58 with old devices = 52.9%

Score = 5 × (52.9% / 100%) = 5 × 0.529 = 2.65

Indicator 3: Plan to Upgrade (BAD)

- 70.3% plan to upgrade for better app performance
- Interpretation: This is NEGATIVE → Shows the app is driving device obsolescence.
- We need to invert this: If 70.3% plan to upgrade, then only 29.7% do NOT plan to upgrade (38 people).

Score = 5 × (29.7% / 100%) = 5 × 0.297 = 1.49

Assigning weights within the DL Dimension with different importance for each indicator:

- Performance on Old Devices: 50% (Most important - actual user experience)
- Plan to Upgrade: 30% (Behavioural intention shows future problem)
- Older Device Use: 20% (Important but less than actual performance)

Calculating the Weighted Average:
DL Score = $(Score_1 \times Weight_1) + (Score_2 \times Weight_2) + (Score_3 \times Weight_3)$
Hence:
DL Score = (2.65 × 0.50) + (1.49 × 0.30) + (2.27 × 0.20)
= (1.325) + (0.447) + (0.454)
= 2.23
Final DL Score = 2.2/5.0 (Rounded from 2.23).

Network Utilization (NU): This assesses the network usage and data consumption of the app across the following indicators:

Indicator 1: Mobile Data Dependence (NEGATIVE)

- Primary Access: 94.7% use Mobile Data (121/128)
- Only 5.3% can use Wi-Fi/Offline reliably

Score = 5 × (5.3% / 100%) = 5 × 0.053 = 0.27

Indicator 2: Data Concern (NEGATIVE)

- 70.3% concerned about data usage
- Only 29.7% NOT concerned

Score = 5 × (29.7% / 100%) = 5 × 0.297 = 1.49

Indicator 3: Want Data-Saving (MIXED)

- 85.2% want data-saving features → Shows problem exists
- But also shows demand for improvement
- Interpretation: High demand = current failure

Score = 5 × (14.8% satisfied / 100%) = 5 × 0.148 = 0.74

Therefore; assigning weights to the NU:

- Data Concern: 40% (Direct user pain point)
- Mobile Data Dependence: 35% (Infrastructure limitation)
- Want Data-Saving: 25% (Improvement demand)

Calculating the Weighted Average:
NU Score = (1.49 × 0.40) + (0.27 × 0.35) + (0.74 × 0.25)
= (0.596) + (0.0945) + (0.185)
= 0.876 ≈ 0.9

Final NU Score = 0.9/5.0 = CRITICAL Network Performance.

E-Waste Contribution (EWC) Score Calculation: This assesses the e-waste contribution of the app measured across the following indicators:

- Upgraded for App: 60.2% Yes (77/128)
- Disposed Device: 49.2% Yes (63/128)
- Future Upgrade Plan: 70.3% Yes (90/128)

We normalize to 0-5 Scale (INVERTED - lower is worse). Note that all indicators are NEGATIVE hence we invert them.

Indicator 1: Upgraded Phone for App Usage:

- 60.2% upgraded → 39.8% did NOT upgrade

Score = 5 × (39.8% / 100%) = 1.99

Indicator 2: Disposed Device

- 49.2% disposed → 50.8% did NOT dispose

Score = 5 × (50.8% / 100%) = 2.54

Indicator 3: Future Upgrade Plan

- 70.3% plan to upgrade → 29.7% do NOT plan

Score = 5 × (29.7% / 100%) = 1.49

Assigning weights to the indicators:

- Future Upgrade Plan: 40% (Predicts future e-waste)
- Upgraded for App: 35% (Past e-waste driver)
- Disposed Device: 25% (Historical impact)

EWC Score = (1.49 × 0.40) + (1.99 × 0.35) + (2.54 × 0.25)
= (0.596) + (0.6965) + (0.635)
= 1.93 ≈ 1.9

Carbon Emissions (CE): The "Carbon Emissions" (CE) dimension does NOT calculate the app's actual carbon footprint. That would require technical measurements we don't have access to. It actually measures, User Environmental Awareness (Proxy). We use CE as a "proxy measure" - an indirect indicator that tells us two important things:

a. What we CAN'T measure (Lack Technical Data):

- Actual CO_2 from app servers (Google Cloud/AWS)
- Carbon from manufacturing user devices
- Network transmission emissions

These require server logs, energy source data, and complex lifecycle analysis.

What We CAN Measure (From the Survey Questions):

- Q10: "Do you think it's important for apps to disclose environmental efforts?"
- Q11: "Would you consider using an app less if it had significant environmental impact?"

These measure user awareness and behavioral intention, i.e. a proxy for how much the environmental impact matters to your users. We're testing a logical chain:

High User Awareness (84% say disclosure important)
↓
Environmental Impact Matters to Them
↓
IF they knew the app was high-carbon
↓
THEN 90% would reduce usage (58% Yes + 32% Maybe)
↓
CONCLUSION: The market/community CARES about sustainability

The CE is measured by the following indicators:

- Important to Disclose: 84.4% Yes (108/128)
- Would Reduce Usage: 58.6% Yes + 31.3% Maybe = 89.9% total concern.

We normalize to 0-5 Scale

Indicator 1: Disclosure Importance (POSITIVE)

- 84.4% say environmental disclosure is important
- Score = 5 × (84.4% / 100%) = 4.22

Indicator 2: Would Reduce Usage (POSITIVE)

- 89.9% would reduce or consider reducing usage
- Score = 5 × (89.9% / 100%) = 4.50

Assigning weights to the CE indicators:

- Would Reduce Usage: 60% (Behavioral intention more important)
- Disclosure Importance: 40% (Awareness)

CE Score = (4.50 × 0.60) + (4.22 × 0.40)
= (2.70) + (1.688)
= 4.39 ≈ 4.4

Final CE Score = 4.4/5.0 = EXCELLENT User Environmental Awareness

Algorithm 3.2: MSO-SVM parameter optimization with look-ahead

IV. RESULT AND DISCUSSIONS

1. Respondent Characteristics

A total of 128 valid responses were collected from users of the RedRose One App across gombe and kano states in Nigeria. The respondents comprised various categories of field personnel involved in Seasonal Malaria Chemoprevention (SMC) implementation, including Technical and Training Assistants (TTAs), Cluster Supervisors, Community Drug Distributors (CDDs), and other field supervisors. This diverse representation ensured that the findings reflected the experiences of users operating under different responsibilities and working conditions during mass campaign implementation.

2. Energy Consumption

One of the primary objectives of this study was to evaluate the energy efficiency of the RedRose One App from the users' perspective. The findings revealed that a considerable proportion of respondents experienced noticeable battery drain while using the application during campaign activities. Users who interacted with the application multiple times daily were more likely to report increased battery consumption compared to occasional users.

Although the application supports certain features intended to improve usability, such as offline functionality, many respondents indicated that they rarely used these features specifically for reducing battery consumption. Furthermore, respondents rated the application's balance between performance and energy efficiency as moderate, suggesting that while the application performs adequately, there remains room for optimization in terms of power management.

3. Device Lifecycle

The results also revealed important insights regarding device sustainability. A significant number of respondents reported using the application on older or second-hand smartphones, demonstrating that the application remains accessible on a wide range of devices.

However, a noticeable proportion of participants indicated that they had either upgraded their smartphones or planned to upgrade them to improve application performance. Additionally, some respondents reported replacing devices because of compatibility concerns.

These findings suggest that although the RedRose One App supports legacy devices to some extent, continued improvements in device optimization could reduce premature device replacement and ultimately contribute to reducing electronic waste.

4. Network Utilization

Network utilization emerged as one of the most significant findings of the study. Most respondents primarily accessed the application using mobile data rather than Wi-Fi.

Furthermore, many respondents believed that the application consumed a considerable amount of their mobile data allowance. This perception was reinforced by the overwhelming support for introducing additional data-saving features within future versions of the application.

These findings demonstrate that data efficiency represents both an economic and environmental issue within ICT4D implementations. High mobile data consumption not only increases operational costs for users but also contributes indirectly to higher energy consumption within telecommunications infrastructure.

5. Environmental Awareness

The study found relatively high environmental awareness among respondents. Most participants agreed that mobile applications should disclose their environmental sustainability practices.

Similarly, many respondents indicated that knowledge of an application's environmental impact could influence their future usage decisions. This finding demonstrates increasing awareness among ICT4D users regarding sustainable technology and suggests that environmental considerations are becoming an important aspect of user expectations.

6. Electronic Waste

Electronic waste (e-waste) remains an emerging concern within mobile ICT4D deployments. While only a proportion of respondents reported replacing devices directly because of application compatibility, many indicated that they would upgrade to newer devices if their existing phones became incompatible.

This behavior highlights the indirect environmental consequences of application design decisions. Applications requiring increasingly powerful hardware may accelerate device replacement cycles, thereby increasing electronic waste generation in developing countries where formal recycling systems remain limited.

7. Environmental Mobile App Impact Assessment (EMAIA)

The Environmental Mobile App Impact Assessment (EMAIA) framework developed in this study was used to evaluate five sustainability dimensions:

- Energy Consumption
- Device Lifecycle
- Network Utilization
- Environmental Awareness
- Electronic Waste

The aggregated assessment indicates that the RedRose One App demonstrates moderate environmental sustainability. While the application provides significant operational benefits for public health campaigns, several sustainability challenges remain, particularly regarding battery usage, mobile data consumption, and long-term device sustainability.

The EMEIA framework successfully identified areas requiring optimization while also demonstrating its applicability as a practical sustainability assessment tool for ICT4D mobile applications.

V. DISCUSSIONS

This study investigated the environmental impact of the RedRose One App used during mobile health campaigns in Nigeria. While ICT4D applications have significantly improved data collection, beneficiary management, monitoring, and reporting within public health interventions, limited attention has been given to their environmental implications.

To address this gap, the study proposed the Environmental Mobile App Impact Assessment (EMAIA), a novel user-centred framework for evaluating the sustainability of mobile ICT4D applications. Using responses from 128 field users, the framework assessed five key dimensions: energy consumption, device lifecycle, network utilization, environmental awareness, and electronic waste.

The findings indicate that although the RedRose One App effectively supports large-scale health campaigns, opportunities exist to improve its environmental performance. High battery consumption, considerable mobile data usage, and increasing pressure on device upgrades were identified as the major sustainability concerns.

Conversely, users demonstrated a strong awareness of environmental sustainability and expressed support for greener application features, suggesting that sustainability considerations are becoming increasingly important among ICT4D users.

VI. CONCLUSION

One of the key contributions of this research is the development of the EMAIA framework, which extends existing green computing research by shifting the focus from data centre and infrastructure-level metrics toward user-centred sustainability assessment. Unlike conventional metrics such as Power Usage Effectiveness (PUE) and Carbon Usage Effectiveness (CUE), EMAIA captures the environmental experiences of end users operating in low-resource environments where mobile devices are the primary computing platform.

The study therefore contributes to the growing body of knowledge on Green ICT4D by providing an adaptable sustainability assessment framework that can be applied to other mobile applications used in humanitarian response, digital health, agriculture, education, and social protection programmes.

Recommendations

Future research should extend the EMAIA framework by incorporating objective measurements such as battery telemetry, application-level energy profiling, server-side energy consumption, and lifecycle carbon assessment. Comparative evaluations involving multiple ICT4D platforms across different countries would further strengthen the framework's validity and support the development of standardized environmental sustainability metrics for mobile ICT4D systems.

Overall, this research demonstrates that environmental sustainability should become a core consideration in the design, deployment, and evaluation of ICT4D applications. As digital technologies continue to expand across developing countries, ensuring that these innovations are both socially beneficial and environmentally responsible will be essential for achieving.

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