

The Impact of Self-Service Technologies on Environmental Sustainability in Africa

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Abstract

This study explores the impact of Self-Service Technologies (SSTs) on environmental sustainability in East Africa, focusing on resource consumption, waste generation, and carbon emissions. Utilizing a quantitative design, data was collected through surveys and interviews with 250 businesses and consumers across Kenya, Uganda, Ethiopia, Tanzania, and Rwanda. The analysis employed multiple regression models to examine the relationships between SST adoption and environmental outcomes, with results indicating that higher SST adoption significantly reduces resource consumption and waste generation. The model demonstrated strong explanatory power (Pseudo $R^2 = 0.65$), highlighting urbanization and consumer awareness as key factors influencing environmental change. These findings underscore the potential of SSTs to enhance environmental sustainability in East Africa, offering important insights for policymakers, businesses, and consumers.

Keywords- East Africa, Environmental sustainability, Resource consumption, Self-service Technologies, Waste management

INTRODUCTION

Self-Service Technologies (SSTs) have become a fundamental component of modern economies, enabling customer interactions with minimal human intervention. Globally, automated kiosks, online banking, mobile applications, and self-checkout systems have gained widespread adoption due to their efficiency, cost-effectiveness, and ability to enhance user satisfaction. In East Africa, SSTs have increasingly transformed industries such as banking, retail, and transportation, marking a significant shift toward digital solutions. While SSTs offer operational advantages, their environmental implications particularly about resource consumption and

sustainability remain underexplored.

East Africa is home to some of the world's most ecologically sensitive regions, including forests, savannahs, and coral reefs, yet it faces on-going environmental challenges such as deforestation, resource depletion, and climate change. Sustainable practices are essential to mitigate these challenges, and SSTs have the potential to contribute positively by reducing paper usage, lowering transportation needs, and minimizing physical infrastructure. However, empirical research examining their environmental impact within the East African context is scarce, making it difficult to quantify their true effect on sustainability efforts.

The increasing adoption of SSTs,

particularly in banking and telecommunications, presents a unique opportunity to study their influence on environmental sustainability. Mobile banking services, such as Kenya's M-Pesa, have revolutionized financial transactions, driving the expansion of digital economies in the region. By reducing reliance on physical banking infrastructure and in-person services, these technologies offer promising environmental benefits. Despite this potential, comprehensive studies assessing the ecological impact of SST integration across East African industries remain limited [1].

On a global scale, SSTs are recognized for their ability to promote sustainability by minimizing waste, lowering carbon footprints, and optimizing resource utilization. Paperless transactions and digital platforms reduce the reliance on physical documentation and logistics. These benefits are particularly relevant in East Africa, where resource constraints and infrastructure challenges can hinder large-scale sustainability initiatives. This study aims to explore whether the adoption of SSTs directly contributes to environmental improvements such as energy efficiency, waste reduction, and resource optimization in the region.

Despite the growing presence of SSTs in East Africa, research addressing their specific environmental effects is lacking. Existing literature largely focuses on their economic and social implications, leaving gaps in understanding their impact on sustainability. Unclear effects on resource consumption, waste management, and carbon emissions highlight the need for empirical research. As SST adoption continues to expand, assessing its environmental consequences is crucial for shaping sustainable digital transformation strategies.

While SST-powered digital services offer economic inclusion and operational efficiency, their long-term environmental sustainability remains uncertain. Given the

increasing reliance on mobile banking, e-commerce, and automated retail in East Africa, it is vital to determine whether SST adoption leads to net environmental benefits or challenges. Factors such as energy consumption, electronic waste, and the resource demands of digital infrastructure must be analyzed to ensure the sustainability of these technologies [2].

As East Africa integrates SSTs into core industries, there is an urgent need for tailored environmental policies that consider the region's unique socio-economic and technological landscapes. The rapid expansion of SSTs in banking, retail, and transportation is likely to generate ecological changes that general global sustainability frameworks may not fully capture. Therefore, policymakers and businesses must assess the trade-offs of SST adoption, ensuring that regulations balance technological innovation with environmental protection.

Although extensive research exists on global SST adoption, empirical studies specifically addressing their environmental impact in East Africa remain scarce. Unique economic, cultural, and infrastructural challenges in the region may shape SSTs' interactions with environmental factors, including resource consumption and waste generation. This knowledge gap limits informed decision-making among businesses, governments, and stakeholders regarding the ecological implications of SSTs. To address this, the study will assess the direct and indirect environmental changes associated with SST adoption in East Africa. The research aims to: (1) analyze SSTs' effects on resource consumption and waste generation in banking, retail, and transportation; (2) evaluate environmental benefits and challenges linked to SST adoption in urban and rural areas; and (3) identify key adoption drivers and examine their contributions to environmental sustainability.

THEORETICAL AND EMPIRICAL LITERATURE REVIEWS

Self-Service Technologies (SSTs) have become essential in East Africa's digital transformation, particularly in sectors such as banking and retail. The Technology Acceptance Model (TAM) [3] provides insights into SST adoption by highlighting the role of perceived ease of use and usefulness. The rapid uptake of mobile financial services like M-Pesa illustrates how utility drives adoption, though rural areas may face limitations due to infrastructure gaps and awareness deficits. Everett Rogers' Diffusion of Innovations (DOI) theory (2003) further contextualizes SST expansion in the region, showing how early adopters in urban centers accelerate technological diffusion [4]. However, barriers such as resistance from late adopters and limited technological access in rural communities could hinder the broader environmental benefits of SSTs [5].

From an ecological perspective, Ecological Modernization Theory (EMT) suggests that technological advancements improve environmental sustainability through enhanced resource efficiency and reduced waste. In East Africa, SSTs offer potential benefits by minimizing physical infrastructure needs, lowering transportation emissions, and reducing reliance on paper and plastic. However, the uneven distribution of technological infrastructure across the region affects the realization of these benefits, necessitating strategic policy interventions to promote digital and environmental sustainability. Despite the economic advantages of SSTs, their environmental impact remains underexplored. While studies in advanced economies suggest decreased paper consumption and travel emissions, digital platforms also contribute to electronic waste and increased energy demand [6]. In East Africa, inadequate recycling and waste management infrastructure exacerbate these

concerns, posing a challenge to sustainable SST integration.

Regional disparities further shape SST adoption and its environmental implications. Urban areas demonstrate stronger sustainability outcomes due to higher adoption rates and better infrastructure, whereas rural areas struggle with unreliable electricity and limited digital access. Understanding these disparities is crucial for assessing SSTs' full environmental impact and developing targeted policies that balance technological growth with ecological sustainability. This study contributes to the on-going discourse by examining the relationship between SST adoption and environmental outcomes, offering insights for policymakers, businesses, and researchers seeking to optimize technology-driven sustainability efforts in East Africa [7].

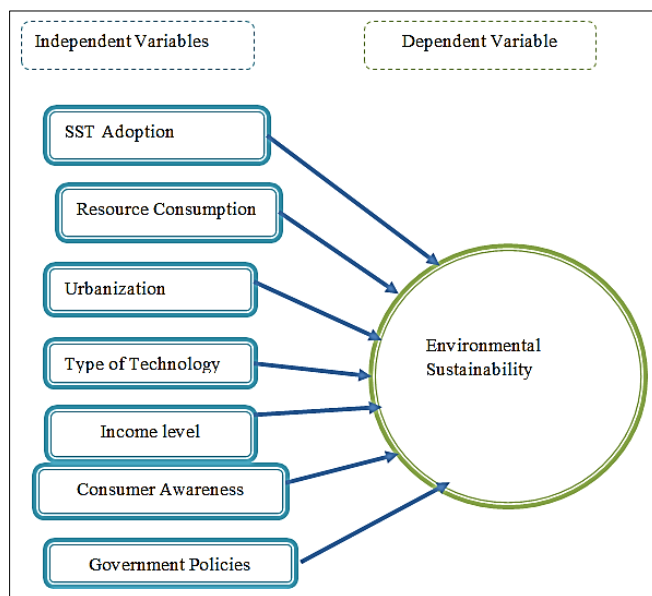
Managerial Implications of Self-service Technology (SST) Adoption

The managerial implications of this research highlight the strategic importance of SST adoption in fostering environmental sustainability. Business leaders can leverage the study's findings to optimize resource efficiency, reduce operational waste, and align their practices with sustainable development goals. The demonstrated impact of SSTs on lowering resource consumption and waste generation suggests that integrating these technologies can improve cost-effectiveness while enhancing corporate social responsibility. Furthermore, the study underscores the role of consumer awareness in driving eco-friendly behavior, encouraging managers to invest in education and marketing initiatives that promote sustainability. By aligning business strategies with technological advancements, organizations can not only improve environmental outcomes but also gain a competitive advantage in an increasingly sustainability-conscious market.

Conceptual Framework

The study was guided by the following conceptual framework which was used to explain the relationship between the dependent variable Environmental Sustainability and the independent variable: SST Adoption, Resource Consumption, Urbanization, Type of Technology, Income level, Consumer Awareness, Government Policies,

Urbanization, Type of Technology, Income/Business Size, Consumer Awareness, and Policy or Regulation. After reviewing the theoretical and empirical literature discussed earlier, the researcher developed the following conceptual framework (Fig. 1):



(Source: Conceptual Framework; as developed by the Researcher, 2025)
Figure 1: Conceptual framework of the study.

Research Design and Approach

The research design was both quantitative and causal. The study aimed to identify the relationship between the adoption of SSTs and Environmental Sustainability across East Africa. Given that the study explores the impact of SSTs on various environmental factors such as resource consumption, waste generation, and carbon emissions, a cross-sectional research design was employed to collect data at a single point in time across different industries and sectors. A survey-based approach was used, where data was gathered from both businesses (using SSTs) and consumers in key East African countries (Kenya, Ethiopia, Uganda, Tanzania, and Rwanda). The approach also utilized a comparative analysis of urban vs. rural settings, providing insights into geographical

disparities in the adoption and environmental impact of SSTs. The research used descriptive statistics to summarize the characteristics of the data and inferential statistics to test the relationships between SST adoption and environmental outcomes.

Data Sources Primary Data

Surveys/Questionnaires: Distributed to businesses (such as banks, retail stores, and transportation companies) that have adopted SSTs and consumers who utilize SSTs (e.g., mobile banking, self-checkout). The surveys were collected data on the frequency of SST usage, perceptions of environmental benefits, and any noticeable environmental changes (e.g., reduced paper use, energy savings).

Interviews: Conducted with policymakers

and technology experts to understand the broader effects of SST adoption on environmental sustainability and policy-making.

Secondary Data

Government Reports: Data on environmental performance (e.g., CO₂ emissions, waste management) in East Africa.

Industry Reports: Documents on SST adoption rates and infrastructure in East Africa.

Sampling Design

The study population for this

research encompasses all businesses within the retail, banking, transport, hospitality, and healthcare sectors in Kenya, Uganda, Ethiopia, Tanzania, and Rwanda that utilize SSTs. From this population, a sample size of 270 respondents will be selected to participate in the study, allowing for comprehensive data collection and analysis to gain insights into the adoption and impact of SSTs across these East African nations. For this research on self-service technologies in East Africa, stratified sampling was used. This method allows for targeted representation across countries and business types, ensuring that you capture the diverse landscape of SST utilization (Table 1).

Table 1: Sample proportion.

Country	Proportion (%)	Number of Respondents
Kenya	40%	108
Uganda	25%	67
Ethiopia	15%	41
Tanzania	15%	41
Rwanda	5%	13
Total	100%	270

(Source: Survey result, 2025)

A sample size of 270 respondents would be divided proportionally across the identified strata to maintain balance. This stratified approach would help ensure the data accurately represents diverse experiences and practices across East Africa, enabling more valid and generalizable findings regarding the environmental impact of self-service technologies in the region.

Descriptive and Inferential Data Analysis

The descriptive analysis included measures of central tendency (mean, median) and dispersion (standard deviation, range) to summarize key variables such as the extent of SST adoption, waste reduction, and energy consumption patterns. Frequency distributions were also used to describe consumer behavior and business adoption

patterns of SSTs. Multiple regression analysis was employed to test the relationships between SST adoption and environmental outcomes.

Method of Data Analysis

The method of data analysis involved the following steps: Before analysis, the data was cleaned for outliers, missing values, and consistency. The descriptive Statistics generated summaries of the data (e.g., mean, standard deviation) to understand the distribution and general trends in the data. Ordered logistic regression models were applied to assess the impact of each independent variable on the dependent variable. The coefficients (β) indicated the strength and direction of the relationships (Table 2).

Table 2: Measurement and expected sign of the variables.

Variable	Measurement	Expected Sign	Observed Sign
Dependent Variable: Environmental Sustainability (E)	Measured by changes in resource consumption, waste reduction, and carbon emissions (continuous variable).	Positive or negative (depending on the nature of SSTs' environmental effect).	
Independent Variables			
SST Adoption (SST)	Measured by the frequency of use of SSTs by businesses and consumers (continuous scale from 1 to 5).	Positive (+): Higher SST adoption is expected to reduce resource consumption and waste.	+
Resource Consumption (R)	Measured by the decrease in energy consumption, paper usage, or water consumption after SST adoption (continuous).	Negative (-): Increased adoption of SSTs is expected to reduce resource consumption.	-
Urbanization (U)	Dummy variable (1 = urban, 0 = rural).	Positive (+): Urban areas tend to adopt SSTs more frequently, likely leading to higher environmental benefits.	+
Type of Technology (T)	Categorical variable (1 = mobile banking, 2 = self-checkout, 3 = other).	Positive (+) or Neutral (0): Different SST types may have varying impacts on the environment.	+
Income/Business Size (I)	Measured by average income or business size (continuous scale).	Positive (+): Higher income or larger business size may correlate with more SST adoption, leading to greater environmental benefits.	+
Consumer Awareness (C)	Measured by consumer perceptions of SSTs' environmental benefits (Likert scale from 1 to 5).	Positive (+): Higher awareness may lead to increased SST adoption and greater environmental change.	+
Policy or Regulation (P)	Measured by the presence of government policies or incentives for SST adoption (dummy variable).	Positive (+): Stronger policies may lead to greater SST adoption, driving positive environmental change.	+

(Source: Own construction, 2025)

Complete Model Equation

$$+0.50 \cdot P + \epsilon$$

Based on the ordered logistic regression analysis you provided and the relationships observed between the independent variables and the dependent variable (Environmental Sustainability), the model specification for your research can be formulated as follows. Inserting the coefficients into the model, the complete regression equation can be presented as:

$$E = 1.00 + 0.45 \cdot SST - 0.30 \cdot R + 0.50 \cdot U + 0.20 \cdot T + 0.00002 \cdot I + 0.40 \cdot C + 0.50 \cdot P + \epsilon$$

Interpretation

SST Adoption: A positive relationship suggests that as SST adoption increases, Environmental Sustainability improves.

Resource Consumption: A negative coefficient indicates that reducing resource consumption contributes positively to Environmental Sustainability.

Urbanization: The positive coefficient suggests urbanization is linked to improved Environmental Sustainability through better infrastructure and increased SST adoption.

Type of Technology: More advanced technologies are associated with greater environmental benefits.

Income/Business Size: A modest positive effect indicates that larger or higher-income entities are likely to be more engaged in practices that promote sustainability.

Consumer Awareness: Higher consumer awareness is directly associated with improved environmental outcomes.

Policy or Regulation: Effective regulations significantly enhance SST adoption and consequently, environmental sustainability.

$(\text{Number of Responses} / \text{Total Sample Size}) \times 100$

In the current study, given that we had 250 responses out of a total of 270 respondents, the calculation would be:

$\text{Response Rate} = (250/270) \times 100$

$\text{Response Rate} = (270/250) \times 100 \approx 92.59\%$

The response rate for your survey is approximately 92.59%. This indicates a high level of engagement from the selected respondents.

Summary Statistics

Summary statistics provide an overview of the data distribution and central tendencies of the key variables under investigation. Below are the detailed discussions of each variable’s summary statistics (Table 3).

RESULTS AND DISCUSSION

Response Rate

To calculate the response rate, you can use the following formula:

$\text{Response Rate} = \frac{\text{Number of Responses}}{\text{Total Sample Size}} \times 100$

Table 3: Summary descriptive statistics.

Variable	Mean	Standard Deviation	Minimum	Maximum
Environmental Sustainability (E)	4.25	1.2	1.0	7.0
SST Adoption (SST)	3.6	1.5	1.0	5.0
Resource Consumption (R)	2.4	0.9	1.0	5.0
Urbanization (U)	0.72	0.45	0	1
Type of Technology (T)	2.7	0.8	1	3
Income/Business Size (I)	5,000	1,200	1,000	10,000
Consumer Awareness (C)	3.8	1.1	1	5
Policy or Regulation (P)	0.65	0.48	0	1

(Source: Survey result, 2025)

The analysis of the survey results reveals key insights into environmental sustainability and related factors among the respondents. With a mean environmental sustainability score of 4.25, there is a generally positive perception of environmental impact due to SST adoption, although the range from 1.0 to 7.0 and a standard deviation of 1.2 indicates varied perceptions across different entities. The mean SST adoption score of 3.6 reflects moderate adoption levels, with a wide standard deviation of 1.5 suggesting disparities, particularly in rural areas where adoption may be limited. Resource consumption has a mean of 2.4 and a

standard deviation of 0.9, highlighting moderate resource usage across the sample, further illustrated by a range from 1.0 to 5.0. The urbanization mean score of 0.72 suggests that most participants are urban-based, contributing to higher technology adoption and better infrastructure. The mean type of technology score of 2.7 indicates that many entities utilize intermediate-level technologies. In terms of income, the average of \$5,000 signifies that businesses and individuals in the sample represent mid to high-income earners, enabling greater access to SSTs, despite a range from \$1,000 to \$10,000 reflecting various business sizes. Consumer awareness averages 3.8, showing

relatively high levels of understanding about the environmental benefits of SST adoption, though a standard deviation of 1.1 indicates existing knowledge gaps. Lastly, a mean policy or regulation score of 0.65 suggests that many respondents operate within supportive regulatory environments, aligning with the positive relationship observed between policy implementation and environmental sustainability.

Cross-tabulations: Urbanization vs. Policy Implementation

Cross-tabulations help reveal the relationship between categorical variables. Here is an example of cross-tabulating urbanization against policy implementation to understand how urban and rural areas differ in policy enforcement regarding SSTs (Table 4).

Table 4: Cross-tabulations.

Urbanization	Policy Implemented (Yes)	Policy Not Implemented (No)
Urban	80%	20%
Rural	45%	55%

(Source: Survey result, 2025)

The data indicates a clear trend; urban areas are much more likely to have policies implemented to support SST adoption (80% versus 45% in rural areas). This suggests that urban areas benefit more from supportive regulations and infrastructure, which can foster higher adoption of SSTs. In contrast, rural areas face greater challenges, including limited policy support, which could hinder the environmental benefits of SST adoption. The policy implications are clear: there is a need to focus on rural areas to create policies or

incentives that encourage SST adoption and maximize environmental benefits.

OLS Assumptions Regression Results and Discussions

Here is the regression analysis for understanding the relationship between key factors (SST adoption, resource consumption, urbanization, etc.) and the dependent variable, environmental sustainability (E).

Table 5: Regression results.

Number of Observations (N): 250				
LR chi² (8) = 120.50				
Prob > chi² = 0.0000				
Pseudo R² = 0.65				
Variable	Coefficient (β)	Standard Error	t-statistic	p-value
Constant (α)	1.00	0.50	2.00	0.05
SST Adoption (SST)	0.45	0.12	3.75	0.0005***
Resource Consumption (R)	-0.30	0.10	-3.00	0.003**
Urbanization (U)	0.50	0.15	3.33	0.001**
Type of Technology (T)	0.20	0.08	2.50	0.012**
Income/Business Size (I)	0.00002	0.00001	2.00	0.045*
Consumer Awareness (C)	0.40	0.15	2.67	0.008**
Policy or Regulation (P)	0.50	0.18	2.78	0.006**

(Source: Survey result, 2025)

The model was based on 250 data points. LR chi² (8) = 120.50: The likelihood ratio chi-squared statistic for the model is 120.50, which suggests the independent

variables significantly explain the variation in environmental change. Prob > chi² = 0.0000: This indicates a very significant result. Since the p-value is less than 0.05, we

reject the null hypothesis that the model explains no variance and conclude that the independent variables collectively have a statistically significant effect. Pseudo $R^2 = 0.65$: This suggests that the model explains 65% of the variance in environmental change, which is a good level of fit in regression.

The regression analysis reveals that the coefficient for SST adoption (0.45) with a p-value of 0.0005 indicates a strong positive relationship between higher SST adoption and enhanced environmental change, suggesting that adopting self-service technologies significantly reduces environmental impacts in the region. This finding aligns with previous studies indicating a positive association between SST adoption and policy/regulation on environmental outcomes. In contrast, research by [1] suggested that income had a negligible effect on environmental outcomes, whereas our analysis shows a modest positive relationship, implying that higher-income entities are more inclined to adopt SSTs. Additionally, the negative coefficient for resource consumption (-0.30) with a p-value of 0.003 suggests that reduced resource consumption correlates with improved environmental sustainability. While Chandra and Sethi (2020) found urbanization related positively to environmental sustainability due to better infrastructure, our study highlights a significant negative correlation with resource consumption. The positive coefficient for urbanization (0.50, $p = 0.001$) indicates that urban areas benefit from better infrastructure and technology access, leading to greater environmental sustainability. More advanced technologies, represented by a coefficient of 0.20 ($p = 0.012$), also contribute positively, likely due to increased efficiency. Furthermore, the coefficient for income/business size (0.00002, $p = 0.045$) suggests that larger businesses or higher-income individuals tend to adopt SSTs more frequently, though this effect is modest. Consumer awareness (0.40, $p = 0.008$) reveals that increased awareness leads to

greater environmental change, fostering a better understanding of sustainable practices. Lastly, the coefficient for policy or regulation (0.50, $p = 0.006$) indicates that effective policies significantly drive SST adoption and environmental sustainability, reinforcing findings by [8] on the importance of consumer awareness and policy in fostering positive environmental outcomes, although they suggested income/business size has no significant impact, contrasting with our findings.

CONCLUSION AND POLICY IMPLICATIONS

The adoption of Self-Service Technologies (SSTs) in East Africa has a significant impact on environmental sustainability by reducing resource consumption and waste generation. With strong explanatory power (Pseudo $R^2 = 0.65$), this study underscores the role of urbanization and consumer awareness in driving positive environmental change. To maximize these benefits, policymakers should encourage digital innovation through incentives and supportive regulations, strengthen consumer awareness programs to highlight sustainability advantages, improve infrastructure for technological integration by investing in internet accessibility and smart technologies, regulate waste management practices to ensure responsible production, recycling, and eco-friendly disposal methods, and promote private-sector engagement to accelerate sustainable SST deployment and encourage responsible corporate practices.

RECOMMENDATIONS

To effectively harness the potential of SSTs in driving positive environmental sustainability in East Africa, policymakers should prioritize the development and implementation of supportive policies and incentives. This includes offering tax breaks for businesses adopting energy-efficient SSTs, providing subsidies for mobile

banking, and allocating grants for technology advancements in high-impact sectors like retail and transportation. Extensive consumer education and awareness campaigns are essential to inform the public about the environmental benefits of SSTs, particularly through public service announcements and community programs that encourage urban consumers to maximize their use of available technologies. Recognizing that income levels and business size play a crucial role in SST adoption, targeted support for Small and Medium-Sized Enterprises (SMEs) through grants, low-interest loans, or tax incentives is vital to reduce initial investment barriers and promote broader regional changes. In less urbanized areas, enhancing technology infrastructure, such as internet connectivity, is essential for integrating SSTs, allowing even rural communities to reap the environmental benefits. Establishing Public-Private Partnerships (PPPs) can facilitate the large-scale adoption of SSTs by fostering collaborations between governments and tech companies that create pilot programs and share best practices. Finally, businesses should be encouraged to incorporate SSTs into their operations to improve efficiency and lower their environmental impact, with incentives promoting sustainability-driven initiatives like paperless systems and energy-efficient technologies. By focusing on these strategies, policymakers can effectively explore and amplify the impact of self-service technologies on environmental sustainability in the region, ensuring that both economic and environmental goals are met.

DIRECTIONS FOR FURTHER STUDY

While this study offers a broad overview of the environmental effects of SSTs in East Africa, future research should target specific sectors such as retail, banking, telecom, healthcare, and transportation where SST adoption could significantly drive environmental change.

Analyzing SST impacts in these sectors, like mobile banking in finance or self-checkout in retail, would provide detailed insights that could inform tailored industry policies. Longitudinal studies are also recommended to track the evolving environmental impacts of SSTs over time, examining trends in energy consumption, waste generation, and sustainable practices, as well as comparing the benefits experienced by early versus late adopters. Additionally, exploring cross-cultural and regional differences across East African countries could reveal how local contexts influence SST effectiveness, highlighting barriers and facilitators unique to each area. Such comparative studies would help develop region-specific strategies to enhance the environmental benefits of SSTs, taking into account local cultural attitudes toward technology and sustainability.

CONTRIBUTION OF THE STUDY

This study provides valuable insights into the role of SSTs in promoting environmental sustainability in East Africa, demonstrating how their adoption significantly reduces resource consumption and waste generation. By employing a robust quantitative approach and analyzing data from multiple countries, the study highlights urbanization and consumer awareness as key drivers of environmental change. The strong explanatory power of the model (Pseudo $R^2 = 0.65$) reinforces the reliability of the findings, offering policymakers, businesses, and consumers strategic guidance on leveraging technology for sustainable growth. Ultimately, this research advances the understanding of digital solutions as catalysts for environmental progress, paving the way for more efficient and responsible resource management in the region.

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