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The New Elsan Evaluation of Environmental Impact (EEEI) Method for the Assessment of Environmental Impacts of Industrial Activities in Rural Communities

Hassan Elsan Mansaray[1], Victor Tamba Simbay Kabba[2], Hebert Borboh Kandeh[3]

[1]Department of Human Resource and Management, Institute of Public Administration and Management (IPAM), University of Sierra Leone.

[2,3]Institute of Geography and Development Studies, School of Environmental Sciences, Njala University.

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Corresponding Author:
Hassan Elsan Mansaray

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ABSTRACT: The Elsan Evaluation of Environmental Impact (EEEI) method represents a transformative approach to assessing environmental impacts in rural communities affected by industrial activities, particularly mining. This study focuses on three communities in Tankoro Chiefdom, Sierra Leone—Kanniya, Koakoyima, and Sahr Quee Town—to evaluate the environmental, social, and economic consequences of mining operations. The EEEI method integrates community perceptions with advanced statistical analyses, offering a unique combination of inclusivity and rigour.

Using multivariate statistical techniques, the study identifies significant environmental degradation, including deforestation and water contamination, as well as socio-economic disruptions, such as displacement and loss of traditional livelihoods. Positive impacts, such as job creation and infrastructure development, were observed but were limited in scope and overshadowed by the broader negative consequences. Unlike traditional approaches like the Rapid Impact Assessment Matrix (RIAM), which rely on qualitative scoring, the EEEI method employs a standardised numerical framework, allowing for objective, replicable, and scalable evaluations.

Results demonstrate significant main effects for individual predictors and highlight a moderate interaction effect between the Kanniya and Sahr Quee Town communities. The study concludes that the EEEI method is a robust tool for environmental assessments, capable of revealing critical insights into the interconnected dynamics of industrial impacts. Recommendations are provided for further testing and refinement of the EEEI model across diverse contexts, emphasising its potential for broader application in environmental governance and policymaking.

1.0 INTRODUCTION

Environmental Impact Assessments (EIA) have become an indispensable tool in understanding and mitigating the adverse effects of industrial activities on the environment and communities. With increasing global attention on sustainable development and environmental stewardship, the need for advanced and inclusive assessment methods has never been more critical. Traditional approaches to EIA, such as the Rapid Impact Assessment Matrix (RIAM), have provided a foundation for evaluating environmental impacts (Pastakia & Jensen, 1998). However, these methods often rely heavily on qualitative assessments and expert-driven analyses, which can lack the precision and inclusivity required for contemporary environmental challenges.

The Elsan Evaluation of Environmental Impact (EEEI) method introduces a groundbreaking approach that bridges this gap. Designed specifically to address the complexity of natural ecosystems and their interaction with socio-economic systems. EEEI combines statistical rigour with community-based perspectives. By quantifying stakeholder opinions and integrating them into a structured, numerical framework, the EEEI method provides a more objective and replicable approach to environmental

assessments. This innovation allows for deeper exploration of the interdependencies between environmental, social, and economic factors, which are often overlooked in conventional assessments (Oprea, 2014; Noble 2004).

This study applies the EEEI method to evaluate the impacts of mining activities on three communities—Kanniya, Koakoyima, and Sahr Quee Town in Tankoro Chiefdom, Sierra Leone. Mining activities in rural areas often present a paradox, offering potential economic benefits such as job creation and infrastructure development while simultaneously posing significant risks to environmental integrity and community well-being (Ali et al., 2017). The need to balance these competing dynamics underscores the importance of adopting robust assessment methods like EEEI.

2.0 THE OBJECTIVES OF THIS STUDY ARE THREEFOLD

1. To evaluate the environmental, social, and economic impacts of mining activities in the three communities using the EEEI method.
2. To compare the EEEI method with traditional approaches, highlighting its advantages in precision, inclusivity, and scalability.
3. To propose recommendations for refining and broadening the application of the EEEI model to other contexts.

By employing advanced multivariate statistical techniques, this study seeks to demonstrate how the EEEI method can uncover critical insights into the dynamics of industrial impacts on rural communities. Furthermore, it aims to establish the EEEI framework as a standard for future environmental assessments, contributing to better decision-making and policy formulation for sustainable development.

3.0 METHODOLOGY

The methodology employed in this study is centred on the Elsan Evaluation of Environmental Impact (EEEI) method, which was specifically designed to provide a structured, quantitative, and inclusive approach to environmental impact assessment. Unlike traditional methods, which often rely on qualitative data and expert-driven assessments, EEEI integrates stakeholder opinions and applies statistical analyses to create a more comprehensive and replicable framework (Noble 2004; Glasson et al., 2013).

3.1 Study Area and Sampling

This study was conducted in Tankoro Chiefdom, Kono District, Sierra Leone, focusing on three communities: Kanniya, Koakoyima, and Sahr Quee Town. These communities were selected due to their proximity to mining activities and their diverse socio-economic and environmental contexts. A purposive sampling approach was used to identify respondents who could provide insights into the impacts of mining activities (Bryman, 2016).

3.2 Data Collection

The EEEI method relies on data collected through structured questionnaires and focus group discussions. Respondents were asked to evaluate various environmental, social, and economic factors affected by mining activities. Each response was quantified using a standardised scale, where proportions of stakeholder opinions were converted into numerical values (Ali et al., 2017). For instance:

- 0–20% of respondents agreeing: Score = 1 (Very Low)
- 21–40% agreeing: Score = 2 (Low)
- 41–60% agreeing: Score = 3 (Moderate)
- 61–80% agreeing: Score = 4 (High)
- 81–100% agreeing: Score = 5 (Very High)

This structured approach allowed for the quantification of both positive and negative impacts, enabling more precise statistical analyses.

3.3 Data Preparation and Statistical Analysis

The collected data were processed using IBM SPSS Statistics (Version 25). The EEEI method supports the use of advanced statistical tools to reveal correlations and interdependencies among multiple variables, which is critical for understanding the complex dynamics of industrial impacts. In this study, the following steps were undertaken:

1. Descriptive Statistics: Initial summaries of the data provided an overview of the distribution and central tendencies for key variables (Oprea, 2014).
2. Multivariate Analysis: A General Linear Model (GLM) was applied to assess the main and interaction effects of mining activities on the three communities. Multivariate Analysis of Variance (MANOVA) was employed to examine differences across dependent variables, such as environmental degradation, socio-economic impacts, and community well-being, for each community (Tabachnick & Fidell, 2019).
3. Interaction Effects: The study specifically investigated two-way and three-way interaction effects among the communities to determine whether combined impacts had a compounded effect.

3.4 EEEI Framework

The EEEI method's framework integrates community perspectives into a replicable quantitative model. This is a significant departure from traditional approaches like the Rapid Impact Assessment Matrix (RIAM), which often lack scalability and standardisation (Pastakia & Jensen, 1998). By using community-derived data and advanced statistical tools, EEEI provides a robust mechanism for:

- Quantifying stakeholder opinions.
- Identifying significant predictors of environmental, social, and economic impacts.
- Establishing clear patterns and trends across different impact categories.

3.5 Ethical Considerations

All participants provided informed consent before participating in the study. Confidentiality was maintained, and the research adhered to ethical guidelines for environmental and social impact studies (Glasson et al., 2013).

4.0 RESULTS AND DISCUSSIONS

This section presents the findings of the study, analysing the environmental, social, and economic impacts of mining activities on the three selected communities using the Elsan Evaluation of Environmental Impact (EEEI) method. The results are interpreted using statistical analyses and contextual insights, highlighting the advantages of EEEI over traditional assessment methods.

4.1 Environmental Impacts

The results reveal significant environmental degradation in all three communities, with notable impacts including deforestation, water contamination, and farmland destruction. These effects were most pronounced in Sahr Quee Town, where stakeholders reported high levels of land degradation and pollution. Deforestation was identified as a critical issue, affecting not only biodiversity but also traditional land-use practices. These findings are consistent with prior studies that underscore the environmental costs of unregulated mining activities (Ali et al., 2017; Hilson, 2002).

Water contamination emerged as a common concern across all communities. Streams and wells, critical for household and agricultural use, were reported to have diminished quality due to mining effluents. This aligns with studies highlighting water pollution as a major consequence of mining in sub-Saharan Africa (Kitula, 2006). The EEEI method quantified these impacts with precision, allowing for a nuanced understanding of community-specific challenges.

4.2 Social Impacts

The social impacts of mining activities varied across the three communities but included common themes such as displacement, disruption of traditional practices, and loss of access to ancestral lands. Respondents in Kanniya reported significant displacement, which had a cascading effect on social cohesion and community identity. This corroborates findings from Glasson et al. (2013), who noted that displacement often leads to long-term socio-economic instability.

Interestingly, while mining created some social benefits such as, temporary employment opportunities and infrastructure development - these were largely overshadowed by the negative effects. The EEEI method's integration of community perceptions provided valuable insights into the lived experiences of those directly affected by these activities, distinguishing it from traditional methods that often exclude stakeholder voices (Noble 2004).

4.3 Economic Impacts

Economic impacts presented a paradox. While mining activities injected some financial resources into the communities, these benefits were unevenly distributed and insufficient to offset the environmental and social costs. In Koakoyima, for instance, respondents noted modest increases in business opportunities, but these were limited to short-term gains. Such findings align with studies indicating that mining often creates economic dependencies without fostering sustainable development (Hilson & Maconachie, 2009).

The EEEI framework quantified the economic impacts using a standardised scale, revealing that positive outcomes such as job creation and infrastructure improvements scored lower than expected. This emphasises the need for policies that ensure equitable distribution of benefits and prioritise long-term economic resilience.

4.4 Statistical Analysis of EEEI Data

Using Multivariate Analysis of Variance (MANOVA), significant main effects were observed for the individual communities, confirming that mining activities had distinct impacts across environmental, social, and economic dimensions. For example:

- Environmental impacts: The partial eta squared for environmental predictors was high (≥ 0.65), indicating strong effects across all three communities (Tabachnick & Fidell, 2019).
- Social and economic impacts: Moderate to strong effects were observed for these predictors, with variations depending on the community.

Interaction effects were also explored. The interaction between Kanniya and Sahr Quee Town was statistically significant ($p < 0.01$), suggesting shared vulnerabilities, particularly in environmental degradation. However, no significant three-way interactions were found, indicating that the impacts were largely independent of combined community effects.

4.5 Comparison with Traditional Methods

The EEEI method's integration of stakeholder perceptions and advanced statistical tools provides a clear advantage over traditional methods like the Rapid Impact Assessment Matrix (RIAM). While RIAM offers a qualitative overview, EEEI quantifies impacts with precision, making it more suitable for policy-making and long-term planning (Pastakia & Jensen, 1998). Furthermore, the use of multivariate techniques allowed for a deeper understanding of interdependencies among impact categories, enhancing the comprehensiveness of the analysis (Oprea, 2014).

5.0 COMPARISON WITH TRADITIONAL METHODS

The Elsan Evaluation of Environmental Impact (EEEI) method provides a significant departure from traditional approaches to environmental impact assessment, such as the Rapid Impact Assessment Matrix (RIAM). Traditional methods often lack the precision and inclusivity required for complex, modern environmental challenges. This section outlines the key differences and advantages of the EEEI method, drawing comparisons to RIAM and other conventional frameworks.

5.1 Quantitative Precision

One of the primary strengths of the EEEI method is its ability to quantify environmental, social, and economic impacts using a standardised numerical framework. Unlike RIAM, which relies heavily on qualitative scoring and descriptive weightings, EEEI assigns numerical values to community responses, enabling rigorous statistical analysis (Pastakia & Jensen, 1998). This structured approach ensures consistency and repeatability in assessments, making the method more suitable for comparative studies and policy-making (Noble 2004).

5.2 Integration of Community Perceptions

Traditional methods often prioritise expert-driven analyses, which may not fully capture the lived experiences of affected communities. By contrast, the EEEI method actively incorporates stakeholder opinions, transforming qualitative perceptions into measurable data points (Glasson et al., 2013). This inclusive approach aligns with global calls for participatory decision-making in environmental governance (Reed, 2008). The involvement of community stakeholders not only enriches the assessment but also enhances the legitimacy and acceptance of findings.

5.3 Application of Advanced Statistical Techniques

While RIAM provides a qualitative overview of impacts, it does not utilise statistical tools to explore interdependencies among variables. The EEEI method addresses this limitation by employing multivariate statistical techniques, such as the General Linear Model (GLM) and Multivariate Analysis of Variance (MANOVA) (Oprea, 2014; Tabachnick & Fidell, 2019). These tools reveal complex interactions between environmental, social, and economic factors, offering a more holistic understanding of impacts. For instance, in this study, the EEEI method identified a statistically significant interaction between Kanniya and Sahr Quee Town communities, which traditional methods might have overlooked.

5.4 Scalability and Standardisation

Conventional methods like RIAM lack a standardised framework for evaluating impacts across multiple locations. The EEEI method addresses this gap by utilising a uniform scale (e.g., 0–5), which facilitates comparisons between communities, regions, and even industries. This scalability is particularly valuable for policymakers and practitioners seeking to apply the method across diverse contexts (Noble 2004).

5.5 Environmental, Social, and Economic Dimensions

The EEEI method's ability to integrate and analyse the three pillars of sustainability—environmental, social, and economic impacts—sets it apart from traditional approaches, which often focus narrowly on one dimension (Ali et al., 2017). By encompassing these interrelated aspects, EEEI provides a comprehensive framework for understanding and addressing the multifaceted consequences of industrial activities.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The findings of this study demonstrate the efficacy of the Elsan Evaluation of Environmental Impact (EEEI) method as a robust and inclusive framework for assessing the environmental, social, and economic impacts of industrial activities in rural communities. By integrating community perceptions with advanced statistical techniques. EEEI addresses several limitations of traditional methods, such as the Rapid Impact Assessment Matrix (RIAM), which often lack quantitative precision and inclusivity (Pastakia & Jensen, 1998).

The EEEI method provided critical insights into the distinct and interdependent impacts of mining activities across the three studied communities—Kanniya, Koakoyima, and Sahr Quee Town. Significant environmental degradation, including deforestation and water contamination, was observed alongside socio-economic disruptions such as displacement and loss of traditional livelihoods. While some economic benefits, such as temporary job creation, were noted, they were insufficient to offset the broader negative consequences. These findings align with global studies emphasising the need for more holistic and participatory approaches to environmental impact assessment (Ali et al., 2017; Glasson et al., 2013).

The statistical analysis further validated the EEEI method's ability to uncover significant main effects and moderate interaction effects, particularly between Kanniya and Sahr Quee Town. This highlights the method's capacity to explore complex dynamics that are often overlooked in conventional frameworks (Tabachnick & Fidell, 2019).

6.2 Recommendations

To further refine and expand the applicability of the EEEI method, the following recommendations are proposed:

1. Testing Across Diverse Contexts: Future studies should apply the EEEI framework in different geographic regions and industries to validate its scalability and adaptability. For example, its application in assessing impacts of agricultural expansion or urban development could provide broader insights into its utility (Noble 2004).
2. Longitudinal Studies: Incorporating longitudinal data would allow researchers to evaluate the long-term impacts of industrial activities, particularly on environmental recovery and socio-economic resilience. This approach aligns with the global emphasis on sustainable development and evidence-based policymaking (Reed, 2008).
3. Enhanced Community Engagement: While the EEEI method already integrates stakeholder perceptions, future implementations could further engage community members through participatory workshops and real-time feedback mechanisms. This would not only enrich the dataset but also foster greater local ownership of the findings (Arnstein, 1969).
4. Policy Integration: Policymakers should consider adopting the EEEI framework as a standard for environmental assessments, particularly in regions with high levels of industrial activities. By providing a more comprehensive understanding of impacts, the method can inform evidence-based policies aimed at promoting sustainable development (Ali et al., 2017).
5. Incorporation of Emerging Technologies: Integrating geospatial analysis and remote sensing data with the EEEI framework could enhance its ability to capture spatial patterns of environmental impacts, further strengthening its analytical capacity (Glasson et al., 2013).
6. Capacity Building: Training programmes should be developed for researchers, policymakers, and community leaders to ensure effective implementation and interpretation of the EEEI method. Building local capacity will be crucial for sustaining the method's impact.

6.3 Closing Statement

In conclusion, the EEEI method represents a significant advancement in environmental impact assessment, addressing the shortcomings of traditional approaches while offering a scalable, inclusive, and statistically rigorous framework. Its application has the potential to transform how we evaluate and mitigate the impacts of industrial activities, paving the way for more sustainable and equitable development practices.

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