

# Environmental Quality Management Practices and the Sustainability of Nyarugenge Mining Projects in Rwanda

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**Abstract:** The study examined the effect of environmental quality management practices on the sustainability of mining projects in Nyarugenge District, Rwanda. The study adopted a descriptive and correlational research design using both quantitative and qualitative approaches. Data were collected from 215 respondents, comprising 119 mining company staff respondents and 96 community respondents living around mining project areas in Nyarugenge District. Primary data were collected using structured questionnaires, interviews, and observation checklists, while secondary data were obtained from government reports, policy documents, books, and peer-reviewed journals. Quantitative data were analyzed using descriptive statistics, Pearson correlation analysis, and multiple linear regression analysis, while qualitative data were analyzed using thematic analysis. The findings from the staff respondents indicated that environmental compliance, waste management, land rehabilitation, and environmental monitoring were all positively associated with the sustainability of mining projects. Correlation analysis revealed strong positive relationships between environmental compliance and sustainability ( $r = 0.949$ ), waste management and sustainability ( $r = 0.796$ ), land rehabilitation and sustainability ( $r = 0.962$ ), and environmental monitoring and sustainability ( $r = 0.812$ ), all statistically significant at  $p < 0.01$ . Multiple regression analysis further established that environmental quality management practices jointly had a significant influence on the sustainability of mining projects among staff respondents, with waste management, land rehabilitation, and environmental monitoring emerging as the strongest predictors of sustainability. Similarly, the findings from the community respondents demonstrated that environmental quality management practices positively influenced the sustainability of mining projects. Pearson correlation analysis showed significant positive relationships between environmental compliance and sustainability ( $r = 0.879$ ), waste management and sustainability ( $r = 0.787$ ), land rehabilitation and sustainability ( $r = 0.871$ ), and environmental monitoring and sustainability ( $r = 0.758$ ), all significant at  $p < 0.01$ . Community respondents further indicated that effective waste management, restoration of degraded land, and regular environmental monitoring contributed to reduced environmental pollution, improved environmental protection, and enhanced community well-being. The regression analysis confirmed that environmental quality management practices significantly explained variations in mining project sustainability. The findings revealed that waste management ( $\beta = 0.636$ ,  $p = 0.002$ ), land rehabilitation ( $\beta = 0.552$ ,  $p = 0.036$ ), and environmental monitoring ( $\beta = 0.483$ ,  $p = 0.025$ ) had statistically significant positive effects on the sustainability of mining projects, whereas environmental compliance ( $\beta = 0.210$ ,  $p = 0.421$ ) showed a positive but statistically insignificant effect after controlling for the influence of the other variables.

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## I. INTRODUCTION

The sustainability of mining projects is multidimensional. Environmental sustainability focuses on reducing ecological damage and restoring affected land. Social sustainability concerns community safety, health, participation, and acceptance of mining operations. Economic sustainability relates to the ability of mining projects to remain productive and profitable while meeting environmental

obligations. These dimensions are interconnected because poor environmental management can increase operating costs, attract regulatory sanctions, create community resistance, and reduce the long-term viability of mining projects. For mining projects to be considered sustainable, they must protect the environment, support local communities, and maintain economic viability over time. However, weak implementation of environmental quality management practices has been

identified as a key factor limiting the sustainability of mining projects, particularly in developing countries (UNEP, 2024).

At the global level, mining sustainability concerns are evident in countries such as Canada and Chile, where mine closure, rehabilitation, environmental monitoring, and regulatory compliance have become central components of sustainable mining governance. In Canada, mine closure and reclamation plans are expected to allow adjustments during the life of the mine, adapt to new technologies and environmental regulations, and support progressive reclamation while mining operations are still ongoing (Crown-Indigenous Relations and Northern Affairs Canada, 2022). This demonstrates the importance of integrating land rehabilitation and environmental monitoring throughout the mining project life cycle. International organizations and industry bodies also emphasize the importance of responsible environmental management in mining. The International Council on Mining and Metals (ICMM) promotes responsible mining principles through good practice environmental, social and governance requirements for the mining industry (International Council on Mining and Metals, 2024). Similarly, the World Bank emphasizes the need for mining governance frameworks that protect ecosystems and communities (World Bank Group, 2022). UNEP and the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development also emphasize sound environmental management of minerals and metals, including pollution-free mine closure, rehabilitation, circularity, and improved sustainability practices (UNEP, 2024).

Across Africa, the mining sector remains an important contributor to economic development through job creation, export earnings, infrastructure development, and livelihoods. A significant portion of this contribution comes from artisanal and small-scale mining (ASM) projects, which provides direct employment to millions of people across the continent, particularly in rural areas where alternative income opportunities are limited (World Bank, 2023). However, despite its socio-economic importance, ASM and other mining projects in Africa are widely associated with environmental and sustainability challenges. Weak regulatory enforcement, limited technical capacity, and informal mining practices have contributed to increasing environmental pressures in many mining regions (Ofosu et al., 2020; UNEP, 2021). Regionally, mining operations have been linked to land degradation, deforestation, soil erosion, and contamination of water bodies due to sedimentation and heavy metals. According to the World Bank (2023), environmental risks in mining are often exacerbated by inadequate environmental management systems, limited formalization of mining activities, and insufficient access to cleaner technologies. The report further highlights those environmental impacts are not only ecological but also social, as they directly affect agricultural productivity, health, and livelihoods in mining communities.

In Rwanda, the mining sector plays a significant role in national economic transformation and contributes approximately 3% to the Gross Domestic Product (GDP). The sector generated about USD 1.75 billion in mineral export earnings in 2024, increasing from USD 373 million in 2017,

and is projected to reach USD 2.17 billion in annual export revenues by 2029 under the National Strategy for Transformation (NST-2) (RMB, 2025). The growth of the mining sector has been supported by reforms in mechanization, mineral value addition, professionalization, and exploration activities aimed at improving productivity and competitiveness. Despite its economic contribution, mining activities in Rwanda have increasingly been associated with environmental sustainability challenges. Environmental governance assessments indicate that mining projects contribute to land degradation, soil erosion, sediment discharge into water systems, water pollution, habitat disturbance, and improper waste disposal, particularly where environmental management measures are insufficiently implemented (UNEP, 2021). These environmental impacts pose risks to ecosystems, land productivity, and surrounding communities dependent on natural resources.

Rwanda has established environmental governance and regulatory frameworks through institutions such as Rwanda Mines, Petroleum and Gas Board (RMB) and Rwanda Environment Management Authority (REMA). These institutions are responsible for enforcing Environmental Impact Assessment (EIA) requirements, conducting environmental inspections, monitoring mining operations, and ensuring compliance with environmental regulations, including land rehabilitation after mining activities. The REMA Guidelines for Environmental Impact Assessment for Mining Projects in Rwanda emphasize environmental monitoring, mitigation of impacts, and rehabilitation of mined-out areas as essential components of sustainable mining practices. These guidelines require mining operators to integrate environmental management plans into project design and implementation to minimize environmental degradation and ensure long-term sustainability.

In addition, Rwanda's mining laws require operators to develop rehabilitation plans and comply with environmental protection standards throughout the project lifecycle. Mining companies are also required to implement mitigation measures and restore degraded land after mining activities in line with national environmental regulations. However, despite the existence of these regulatory frameworks and institutional oversight, several reports indicate persistent challenges related to inadequate rehabilitation of mined-out areas, inconsistent implementation of environmental management practices, and weak environmental monitoring at operational level (Muhire et al., 2021; UNEP, 2021). These gaps raise concerns regarding the long-term sustainability of mining projects and the effectiveness of environmental quality management practices within the sector.

#### ➤ *Statement of the Problem*

Despite this economic importance, mining activities have exerted increasing pressure on the environment and local communities. Reports indicate that mining operations in Rwanda have generated significant environmental degradation, including soil erosion, landscape fragmentation, and degradation of water quality in major river systems. Investigations have documented that mineral washing and discharge of untreated wastewater from mining sites

contribute to the pollution of rivers such as the Nyabarongo sections of which pass through Nyarugenge District, threatening aquatic ecosystems and downstream water users (Emmanuel, 2025). Moreover, A report released by the Rwanda Mines, petroleum and Gas Board (RMB) in January 2025 exposes the scale of neglect in the mining sectors. The analysis reveals that 994 sites, including 439 mining areas (44%) and 555 quarries (56%), have been exploited without proper rehabilitation across various regions of the country over nearly a century. The report further underscores the need for approximately 26 billion Rwandan francs to restore these areas to a sustainable state (Fulgence, 2025).

Furthermore, mining-related contamination, including potential heavy metals from ore processing, poses additional risks to human health and ecosystem services when these pollutants infiltrate water intake systems and bioaccumulate in aquatic organisms. The combination of increased sediment loads and chemical contaminants necessitates integrated catchment interventions and enhanced regulatory enforcement to safeguard water quality and public health (Rwanda Water Resources Board, 2024). Empirical evidence from Rwanda demonstrates that weaknesses in environmental quality management practices within mining operations can result in severe and long-lasting environmental degradation. Studies conducted in sensitive ecosystems such as the Gishwati Protected Reserve have shown that poor management of mine tailings, erosion control, and wastewater discharge lead to elevated metal concentrations in water and soil, accelerated sedimentation of rivers, biodiversity loss, and threats to human and ecological health (Muhire, et al., 2021).

While Gishwati represents a protected landscape, similar mining-related environmental pressures are increasingly observed in urban and peri-urban settings, including Nyarugenge District, where mining projects coexist closely with dense populations, critical water infrastructure, and economic activities. health (Muhire, et al., 2021). This underscores the need to critically examine how environmental quality management practices are implemented within mining projects in Nyarugenge and how these practices influence the long-term sustainability of such operations. Without effective environmental management frameworks, monitoring, and enforcement, the continued expansion of mining activities risks undermining environmental integrity and sustainable urban development in Rwanda. Therefore, this study seeks to assess the relationship between environmental quality management practices and the sustainability of mining projects in Nyarugenge District, Rwanda.

#### ➤ *Objectives of the Study*

To examine the effect of environmental quality management practices on the sustainability of mining projects in Nyarugenge District, Rwanda

#### • *Specific Objectives*

- ✓ To assess the effect of environmental compliance on the sustainability of mining projects in Nyarugenge District.
- ✓ To evaluate the effect of waste management on the sustainability of mining projects in Nyarugenge District.

- ✓ To assess the influence of land rehabilitation on the sustainability of mining projects in Nyarugenge District.
- ✓ To examine the effect of environmental monitoring on the sustainability of mining projects in Nyarugenge District.

## II. THEORETICAL REVIEW

### ➤ *Sustainability Theory*

Sustainability Theory originates from the Brundtland Commission Report of 1987, formally known as Our Common Future, which defined sustainable development as development that meets present needs without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The theory emphasizes balancing environmental protection, economic development, and social well-being in order to achieve long-term sustainability. The theory argues that development projects should integrate environmental conservation into operational activities so that economic growth does not occur at the expense of ecological systems and community welfare. In the mining sector, Sustainability Theory emphasizes responsible extraction of mineral resources while minimizing environmental degradation, biodiversity loss, water contamination, and land destruction. Sustainable mining therefore requires effective environmental management systems capable of reducing environmental risks associated with extraction activities (UNEP, 2021; World Bank Group, 2022).

Recent literature strongly supports the relevance of sustainability principles within extractive industries. According to the United Nations Environment Programme (UNEP, 2021), sustainable development requires integrated environmental approaches capable of simultaneously addressing climate change, biodiversity loss, pollution, and environmental degradation. UNEP further argues that unsustainable exploitation of natural resources contributes significantly to ecological instability and environmental crises globally. Similarly, the World Bank Group (2022) emphasized that sustainable development depends on effective environmental management systems, institutional accountability, and sustainable use of natural resources. economic development with environmental protection and long-term ecological sustainability.

Within mining projects, Sustainability Theory is directly linked to environmental quality management practices such as environmental compliance, waste management, land rehabilitation, and environmental monitoring. Mining projects that implement sustainable environmental practices are more likely to maintain environmental quality, reduce ecological degradation, improve public health protection, and ensure long-term operational sustainability (UNEP, 2021). The theory is therefore relevant to this study because it explains how environmental quality management practices contribute to environmental sustainability, social sustainability, and economic sustainability of mining projects. The theory further supports the dependent variable of the study, which focuses on sustainability dimensions within mining operations.

### ➤ *Environmental Governance Theory*

Environmental Governance Theory focuses on the role of institutions, regulations, policies, monitoring systems, and governance structures in environmental management and environmental protection. The theory argues that sustainable environmental management depends on effective institutional systems capable of enforcing environmental regulations, ensuring accountability, and promoting responsible use of environmental resources (OECD, 2022; UNEP, 2021). The theory emphasizes that environmental sustainability can only be achieved through strong governance frameworks involving government institutions, regulatory agencies, environmental laws, compliance mechanisms, monitoring systems, and stakeholder coordination. Environmental governance therefore influences how organizations and industries manage environmental risks and comply with environmental standards. According to Naseer et al. (2024), governance quality plays a significant role in strengthening environmental performance and sustainability outcomes through improved environmental accountability systems.

Environmental Governance Theory is particularly relevant within the mining sector because mining activities generate significant environmental risks requiring strong regulatory oversight. Mining projects often affect ecosystems, water systems, biodiversity, and local communities; therefore, effective governance systems are necessary to ensure environmental accountability and environmental sustainability. According to the International Council on Mining and Metals (ICMM, 2020), responsible mining requires strong governance systems capable of managing environmental risks associated with waste disposal, tailings management, rehabilitation, and environmental monitoring.

In Africa, environmental governance challenges remain significant within extractive industries. The African Union Commission and OECD (2024) reported that weak environmental enforcement systems, limited institutional capacity, and inadequate monitoring mechanisms continue to affect sustainability of mining operations across many African countries. The report further observed that environmental degradation associated with mining activities is often linked to poor regulatory implementation and weak compliance systems. In Rwanda, environmental governance within the mining sector is mainly coordinated through the Rwanda Environment Management Authority (REMA) and the Rwanda Mines, Petroleum and Gas Board (RMB). These institutions are responsible for enforcing Environmental Impact Assessment requirements, conducting environmental inspections, monitoring environmental compliance, and ensuring rehabilitation of degraded mining areas.

Recent studies also demonstrate the importance of governance systems in Rwanda's mining sector. Mugoboka et al. (2025) found that environmental compliance and Environmental and Social Impact Assessment systems improve environmental performance within Rwanda's mining sector. However, the study also identified implementation challenges associated with monitoring systems and environmental enforcement. Environmental Governance

Theory is therefore relevant to this study because it explains how environmental regulations, environmental compliance systems, inspections, audits, and institutional monitoring influence implementation of environmental quality management practices and sustainability of mining projects. The theory strongly supports environmental compliance and environmental monitoring variables within the conceptual framework.

### ➤ *Stakeholder Theory*

Stakeholder Theory was originally developed by Freeman (1984) in his seminal work *Strategic Management: A Stakeholder Approach*. The theory explains that organizations achieve sustainable performance when they recognize and respond to the interests, expectations, and concerns of groups affected by their activities rather than focusing exclusively on financial objectives. The theory was later refined and expanded by Freeman et al. (2010) in *Stakeholder Theory: The State of the Art*, which emphasized stakeholder value creation, stakeholder relationships, and organizational responsibility toward multiple stakeholder groups. The theory argues that sustainable organizational performance depends on responsible management of relationships between organizations and stakeholders. Projects are therefore expected to operate in ways that protect stakeholder interests while minimizing negative environmental and social impacts. Within mining operations, stakeholders are directly affected by environmental degradation such as pollution, land destruction, water contamination, biodiversity loss, and ecosystem disturbance resulting from extraction activities (UNEP, 2021; Ofosu et al., 2020).

In Rwanda, environmental impacts associated with mining activities increasingly affect communities living near mining operations. Muhire et al. (2021) observed that mining activities within Gishwati Protected Reserve contributed to biodiversity loss, water contamination, and environmental degradation threatening surrounding ecosystems and local environmental stability. These environmental impacts demonstrate the importance of stakeholder-oriented environmental management systems within mining projects. The theory supports the relationship between environmental quality management practices and sustainability outcomes within mining projects. It further explains why environmental compliance, waste management, land rehabilitation, and environmental monitoring are essential for protecting stakeholder interests and ensuring sustainable mining operations.

### ➤ *Conceptual Framework*

This conceptual framework illustrates the hypothesized relationship between environmental quality management practices and sustainability of mining projects. In this study, environmental quality management practices represent the independent variable and are measured through environmental compliance, waste management, land rehabilitation, and environmental monitoring. These practices are expected to influence the dependent variable, which is the Sustainability of Mining Projects, measured through environmental, social, and economic sustainability outcomes.

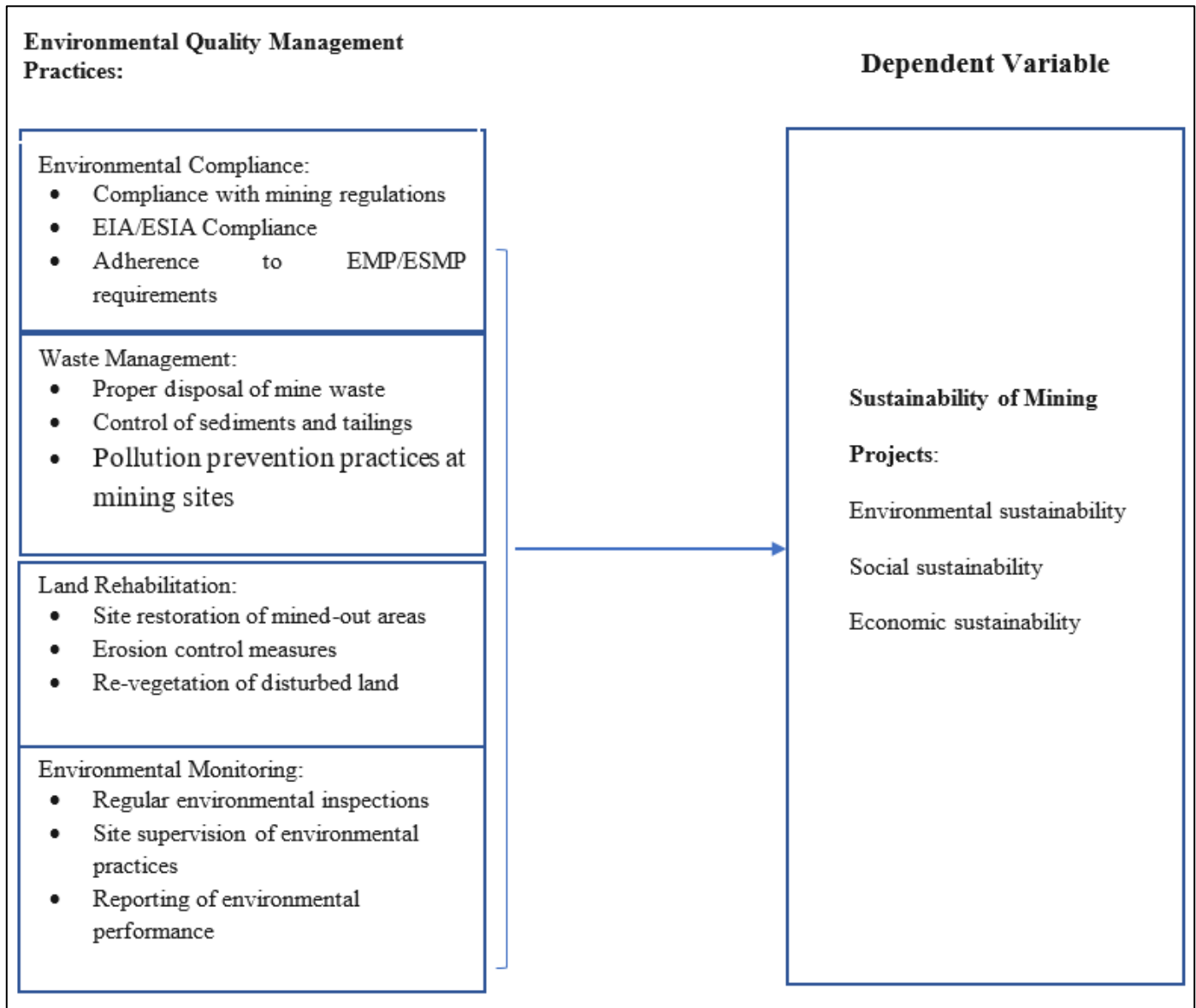


Fig 1 Conceptual Framework

### III. METHODOLOGY

#### ➤ Research Design

This study adopted descriptive and correlational research designs using a mixed-methods approach. The descriptive research design is appropriate because the study seeks to describe the current status of Environmental Quality Management Practices within mining projects operating in Nyarugenge District. Specifically, it helped to describe the level of environmental compliance, waste management, land rehabilitation, environmental monitoring, and sustainability of mining projects. The correlational research design was also appropriate because the study seeks to examine the relationship between Environmental Quality Management Practices and the Sustainability of Mining Projects. Quantitative data was collected through structured questionnaires and analyzed using descriptive statistics, correlation, and regression analysis to measure the effect of the independent variables on the dependent variable.

#### ➤ Study Population

The study population refers to the total group of 465 respondents from whom the researcher intends to obtain information relevant to the study objectives. This study targeted stakeholders associated with mining projects. The target population was drawn from mining projects operating within Nyarugenge District, Rwanda.

#### Sampling Procedures and Techniques

The sample size for this study was determined using Yamane's Formula (1967):

$$n = N / (1 + N(e)^2)$$

Where; n = sample size, N = total population, e = margin of error (0.05)

Therefore:  $n = 465 / [1 + 465(0.05)^2] = 215$  respondents

The study used purposive sampling and simple random sampling techniques. Purposive sampling was used to select site managers, environmental officers, and village representatives because they possess technical knowledge relevant to the study. Simple random sampling was used to select workers and nearby community members to ensure equal chances of participation.

#### ➤ *Data Collection Methods and Instruments / Tools*

The study used both primary and secondary data collection methods. Primary data was collected using questionnaires, interviews, and observation checklists, while secondary data was obtained from journals, reports, books, policies, and environmental documents related to mining sustainability. Primary data refers to original information collected directly from respondents. The study will use questionnaires, interviews, and observation methods. Structured questionnaires were administered to community members, mining project workers, environmental officers, and site managers.

#### ➤ *Data Analysis*

Descriptive statistics were used to summarize respondents' characteristics and their views on Environmental Compliance, Waste Management, Land Rehabilitation, Environmental Monitoring, and Sustainability of Mining Projects. Frequencies, percentages, mean, and standard deviation were used to present demographic information, while means and standard deviations were used to interpret responses from the Likert-scale questionnaire items. Correlation analysis was used to examine the strength and direction of the relationship between Environmental Quality Management Practices and Sustainability of Mining Projects.

Multiple linear regression analysis was used to determine the effect of Environmental Quality Management Practices on the Sustainability of Mining Projects. The regression analysis showed the extent to which each independent variable contributes to changes in the dependent variable while controlling for the influence of other variables. The regression equation was developed in the manner described below:

$$Y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_4x_4 + \varepsilon$$

Y = Sustainability of Mining Projects (Dependent Variable)

$\beta_0$  = Constant term (intercept)

$\beta_1 - \beta_4$  = Regression coefficients of the independent variables

$X_1$  = Environmental Compliance

$X_2$  = Waste Management

$X_3$  = Land Rehabilitation

$X_4$  = Environmental Monitoring

$\varepsilon$  = Error term (other factors affecting sustainability not included in the model)

## IV. RESULTS AND DISCUSSIONS ON THE FINDINGS

The study involved a total of 215 respondents drawn from two main categories. The first category consisted of 119 respondents comprising site managers, environmental officers, mine workers, and village representatives/local leaders, while the second category included 96 nearby community members residing around the selected mining project areas. All sampled respondents successfully completed the questionnaires, resulting in a response rate of 100 percent. Such a response rate enhanced the reliability of the findings by ensuring that the views of all selected participants were adequately represented. All questionnaires were reviewed to verify their completeness and consistency before being coded and entered into the Statistical Package for the Social Sciences (SPSS) Version 23.0 for analysis.

#### ➤ *Reliability Statistics Results*

In this study, the internal consistency of the questionnaires administered to both mining project staff and community members residing near mining project areas was evaluated using Cronbach's Alpha coefficient, which is one of the most widely accepted measures of reliability in social science research.

Table 1 Reliability Statistics Test Results

| Items Category                                                         | Cronbach's Alpha | N  |
|------------------------------------------------------------------------|------------------|----|
| Questionnaire for staff                                                | 0.884            | 12 |
| Questionnaire for community members residing near mining project areas | 0.889            | 10 |

Source: Primary Data from Field Survey (2026)

The questionnaire administered to mining project staff achieved a Cronbach's Alpha coefficient of 0.884, while the questionnaire administered to community members residing near the mining project areas recorded a Cronbach's Alpha coefficient of 0.889. Cronbach's Alpha value of 0.70 or above is considered acceptable, values above 0.80 indicate good reliability, and values exceeding 0.90 demonstrate excellent internal consistency.

#### ➤ *Socio-Demographic Characteristics of Respondents*

A total of 119 respondents participated in the study in the side of staff Respondents, and their responses were analyzed using frequency and percentage distributions. There are also 96 respondents in Socio-Demographic Characteristics of Community Respondents near Mining Sites.

Table 2 Socio-Demographic Characteristics for Staff Respondents

| Variable                                 | Category                              | Frequency (n) | Percentage (%) |
|------------------------------------------|---------------------------------------|---------------|----------------|
| Gender                                   | Male                                  | 81            | 68.1           |
|                                          | Female                                | 35            | 29.4           |
|                                          | No preference to say                  | 3             | 2.5            |
|                                          | <b>Total</b>                          | <b>119</b>    | <b>100.0</b>   |
| Education Level                          | Secondary level                       | 25            | 21.0           |
|                                          | Bachelor's Degree                     | 76            | 63.9           |
|                                          | Master's Degree and above             | 18            | 15.1           |
|                                          | <b>Total</b>                          | <b>119</b>    | <b>100.0</b>   |
| Years of Experience in Mining Activities | Less than 1 year                      | 12            | 10.1           |
|                                          | 1-3 years                             | 36            | 30.3           |
|                                          | 4-6 years                             | 61            | 51.3           |
|                                          | Above 6 years                         | 10            | 8.4            |
|                                          | <b>Total</b>                          | <b>119</b>    | <b>100.0</b>   |
| Category of Respondents                  | Site managers and assistants          | 17            | 14.3           |
|                                          | Environmental officers                | 17            | 14.3           |
|                                          | Workers                               | 79            | 66.4           |
|                                          | Village representatives/local leaders | 6             | 5.0            |
|                                          | <b>Total</b>                          | <b>119</b>    | <b>100.0</b>   |

Source: Primary Data from Field Survey (2026)

The findings indicate that the majority of respondents were male (68.1%), while females accounted for 29.4%, and a small proportion (2.5%) preferred not to disclose their gender. Regarding education level, most respondents held a Bachelor's degree (63.9%), followed by those with secondary education (21.0%), and respondents with a Master's degree and above (15.1%). In terms of work experience, the majority of respondents (51.3%) had 4-6 years of involvement in mining activities, followed by 30.3% with 1-3 years of experience, 10.1% with less than one year, and 8.4% with more than six years. The category of respondents shows that workers constituted the largest group (66.4%), followed equally by site managers/assistants and environmental officers (14.3% each), while village representatives or local leaders accounted for 5.0%.

Table 3 Socio-Demographic Characteristics of Community Respondents Near Mining Sites,

| Variable                                                 | Category                  | Frequency | Percent      | Interpretation                             |
|----------------------------------------------------------|---------------------------|-----------|--------------|--------------------------------------------|
| Gender                                                   | Male                      | 34        | 35.4         | Majority of respondents are female         |
|                                                          | Female                    | 61        | 63.5         |                                            |
|                                                          | No preference             | 1         | 1.0          |                                            |
|                                                          | <b>Total</b>              | <b>96</b> | <b>100.0</b> |                                            |
| Education Level                                          | No formal education       | 6         | 6.3          | Respondents are mainly moderately educated |
|                                                          | Primary education         | 31        | 32.3         |                                            |
|                                                          | Secondary education       | 48        | 50.0         |                                            |
|                                                          | Bachelor's degree         | 9         | 9.4          |                                            |
|                                                          | Master's degree and above | 2         | 2.1          |                                            |
|                                                          | <b>Total</b>              | <b>96</b> | <b>100.0</b> |                                            |
| Years of experience / Involvement with Mining Activities | Less than 1 year          | 8         | 8.3          | Most respondents have medium-term exposure |
|                                                          | 1-3 years                 | 24        | 25.0         |                                            |
|                                                          | 4-6 years                 | 54        | 56.3         |                                            |
|                                                          | Above 6 years             | 10        | 10.4         |                                            |
|                                                          | <b>Total</b>              | <b>96</b> | <b>100.0</b> |                                            |
|                                                          | Resident near mining site | 48        | 50.0         |                                            |

| Variable                             | Category                         | Frequency | Percent      | Interpretation                                     |
|--------------------------------------|----------------------------------|-----------|--------------|----------------------------------------------------|
| <b>Relationship with Mining Area</b> | Farmer near mining site          | 36        | 37.5         | Respondents are mainly local residents and farmers |
|                                      | Business person near mining site | 11        | 11.5         |                                                    |
|                                      | Other                            | 1         | 1.0          |                                                    |
|                                      | <b>Total</b>                     | <b>96</b> | <b>100.0</b> |                                                    |

Source: Primary Data from Field Survey (2026)

The findings show that the majority of respondents were female (63.5%), while 35.4% were male, and a very small proportion (1.0%) did not indicate their gender. This indicates that women constitute the dominant group among community respondents in the study area. The results indicate that half of the respondents (50%) attained secondary education, followed by primary education holders (32.3%), while a smaller proportion had bachelor's degree (9.4%), no formal education (6.3%), and master's level and above (2.1%). The findings reveal that more than half of the respondents (56.3%) have been involved or exposed to mining activities for 4-6 years, followed by 1-3 years (25%), above 6 years

(10.4%), and less than 1 year (8.3%). The results further show that 50% of respondents are residents living near mining sites, while 37.5% are farmers, 11.5% are business people, and 1% fall under other categories.

#### ➤ Descriptive Statistics by Study Objectives (Staff Respondents)

The analysis is structured in line with the specific objectives of the study, focusing on how respondents perceive environmental compliance, waste management, land rehabilitation, environmental monitoring, and the overall sustainability of mining projects.

Table 4 Descriptive Statistics Results from Perceptions of Staff Respondents

| Study Objective/Variable          | Aggregate Mean | SD           | Interpretation                        |
|-----------------------------------|----------------|--------------|---------------------------------------|
| Environmental Compliance          | <b>4.712</b>   | <b>0.562</b> | Very high agreement; high homogeneity |
| Waste Management                  | <b>4.771</b>   | <b>0.507</b> | Very high agreement; high homogeneity |
| Land Rehabilitation               | <b>4.742</b>   | <b>0.512</b> | Very high agreement; high homogeneity |
| Environmental Monitoring          | <b>4.727</b>   | <b>0.513</b> | Very high agreement; high homogeneity |
| Sustainability of Mining Projects | <b>4.752</b>   | <b>0.517</b> | Very high agreement; high homogeneity |

Source: Primary Data from Field Survey (2026)

Waste management had the highest aggregate mean (4.771, SD = 0.507), followed by sustainability of mining projects (4.752, SD = 0.517), land rehabilitation (4.742, SD = 0.512), environmental monitoring (4.727, SD = 0.513), and environmental compliance (4.712, SD = 0.562). Overall, the results demonstrate strong implementation of environmental quality management practices and a high perceived level of sustainability of mining projects in Nyarugenge District.

Table 5 Descriptive Statistics by Community Respondents near Mining Sites,

| Study Objective/Variable          | Aggregate Mean | SD           | Interpretation                            |
|-----------------------------------|----------------|--------------|-------------------------------------------|
| Environmental Compliance          | <b>4.264</b>   | <b>0.947</b> | High agreement; moderate homogeneity      |
| Waste Management                  | <b>4.174</b>   | <b>1.146</b> | High agreement; moderate homogeneity      |
| Land Rehabilitation               | <b>4.281</b>   | <b>0.974</b> | High agreement; moderate homogeneity      |
| Environmental Monitoring          | <b>4.569</b>   | <b>0.658</b> | Very high agreement; high homogeneity     |
| Sustainability of Mining Projects | <b>4.512</b>   | <b>0.802</b> | Very high agreement; moderate homogeneity |

Source: Primary Data from Field Survey (2026)

Environmental monitoring recorded the highest aggregate mean (4.569, SD = 0.658), followed by sustainability of mining projects (4.512, SD = 0.802), land rehabilitation (4.281, SD = 0.974), environmental compliance (4.264, SD = 0.947), and waste management (4.174, SD = 1.146). Overall, the results indicate that environmental monitoring was the most strongly perceived practice among community respondents, while waste management recorded the lowest aggregate mean and the highest variation in responses.

#### ➤ Inferential Statistical Analysis Results

The analysis includes tests of normality, correlation analysis, and multiple linear regression to determine the strength and significance of relationships among variables and to test the study hypotheses.

➤ *Normality Tests*

Normality testing is an important assumption in inferential statistics as it helps determine the suitability of parametric or non-parametric tests. In this study, both

descriptive statistics, Shapiro-Wilk and Kolmogorov-Smirnov tests, as well as graphical methods such as stem-and-leaf plots and Q-Q plots were used to examine the distribution of the sustainability of mining projects.

Table 6 Descriptive Statistics for staff Respondents

|                                   |                                  |             | Statistic | Std. Error |
|-----------------------------------|----------------------------------|-------------|-----------|------------|
| Sustainability of Mining Projects | Mean                             |             | 75.5798   | .67853     |
|                                   | 95% Confidence Interval for Mean | Lower Bound | 74.2362   |            |
|                                   |                                  | Upper Bound | 76.9235   |            |
|                                   | 5% Trimmed Mean                  |             | 76.5472   |            |
|                                   | Median                           |             | 80.0000   |            |
|                                   | Variance                         |             | 54.788    |            |
|                                   | Std. Deviation                   |             | 7.40190   |            |
|                                   | Minimum                          |             | 36.00     |            |
|                                   | Maximum                          |             | 80.00     |            |
|                                   | Range                            |             | 44.00     |            |
|                                   | Interquartile Range              |             | 7.00      |            |
|                                   | Skewness                         |             | -2.495    | .222       |
|                                   | Kurtosis                         |             | 8.430     | .440       |

The descriptive results presented in Table 6 indicate that the sustainability of mining projects had a mean of 75.58 (SD = 7.40) with a 95% confidence interval ranging from 74.24 to 76.92. The median value of 80.00, which is higher than the mean, suggests a concentration of responses toward the upper end of the scale. This is further supported by the negative skewness value of -2.495, which indicates that the distribution is highly left-skewed, meaning that most respondents provided high sustainability ratings with relatively few low scores. In addition, the kurtosis value of 8.430 indicates a leptokurtic distribution, meaning that the data is highly peaked around the mean with a relatively small spread. The minimum and maximum values of 36 and 80, respectively, with a range of 44, further show that while there is some variation in responses, most values are clustered at higher levels.

Table 7 Descriptive statistics for Community Respondents near Mining Sites,

|                                   |                                  |             | Statistic | Std. Error |
|-----------------------------------|----------------------------------|-------------|-----------|------------|
| Sustainability of Mining Projects | Mean                             |             | 75.5208   | .77530     |
|                                   | 95% Confidence Interval for Mean | Lower Bound | 73.9817   |            |
|                                   |                                  | Upper Bound | 77.0600   |            |
|                                   | 5% Trimmed Mean                  |             | 76.5255   |            |
|                                   | Median                           |             | 80.0000   |            |
|                                   | Variance                         |             | 57.705    |            |
|                                   | Std. Deviation                   |             | 7.59637   |            |
|                                   | Minimum                          |             | 36.00     |            |
|                                   | Maximum                          |             | 80.00     |            |
|                                   | Range                            |             | 44.00     |            |
|                                   | Interquartile Range              |             | 7.00      |            |
|                                   | Skewness                         |             | -2.620    | .246       |
|                                   | Kurtosis                         |             | 9.245     | .488       |

The results show that the mean value of sustainability is 75.5208 with a standard error of 0.77530, indicating a relatively high central tendency of responses. The 95% confidence interval ranges from 73.9817 to 77.0600, suggesting that the true population mean is likely within this interval. The 5% trimmed mean of 76.5255 and median of 80.0000 indicate that most responses are clustered toward higher values. The variance of 57.705 and standard deviation of 7.59637 show moderate dispersion in responses. The

minimum and maximum values of 36.00 and 80.00, respectively, give a range of 44.00, while the interquartile range of 7.00 suggests relatively concentrated middle responses. The distribution is negatively skewed with a skewness value of -2.620 (SE = 0.246), indicating that most responses are concentrated at the higher end of the scale. The kurtosis value of 9.245 (SE = 0.488) shows a highly peaked distribution, meaning responses are strongly clustered around the mean.

Table 8 Tests of Normality for staff Respondents

|                                                           | Kolmogorov-Smirnov <sup>a</sup> |     |      | Shapiro-Wilk |     |      |
|-----------------------------------------------------------|---------------------------------|-----|------|--------------|-----|------|
|                                                           | Statistic                       | df  | Sig. | Statistic    | df  | Sig. |
| Sustainability of Mining Projects<br>(Dependent Variable) | .279                            | 119 | .000 | .654         | 119 | .000 |
| a. Lilliefors Significance Correction                     |                                 |     |      |              |     |      |

The results show that the Kolmogorov-Smirnov test produced a statistic of 0.279 ( $p = 0.000$ ), while the Shapiro-Wilk test produced a statistic of 0.654 ( $p = 0.000$ ). In both cases, the significance values are less than 0.05. These results indicate that the data significantly deviates from a normal distribution. In strict statistical terms, this suggests a violation of the normality assumption. However, given the relatively large sample size ( $n = 119$ ), the Central Limit Theorem supports the continued use of parametric techniques, as regression and correlation analyses remain robust under moderate violations of normality.

Table 9 Tests of Normality for Community Respondents near Mining Sites,

|                                       | Kolmogorov-Smirnov <sup>a</sup> |    |      | Shapiro-Wilk |    |      |
|---------------------------------------|---------------------------------|----|------|--------------|----|------|
|                                       | Statistic                       | df | Sig. | Statistic    | df | Sig. |
| Sustainability of Mining Projects     | .284                            | 96 | .000 | .644         | 96 | .000 |
| a. Lilliefors Significance Correction |                                 |    |      |              |    |      |

The Kolmogorov-Smirnov test produced a statistic of 0.284 with  $df = 96$  and  $Sig. = 0.000$ , while the Shapiro-Wilk test recorded a statistic of 0.644 with  $df = 96$  and  $Sig. = 0.000$ . Since both significance values are less than 0.05, the results indicate that the data for sustainability of mining projects is not normally distributed.

#### ➤ Correlation Analysis

The analysis was used to examine both the strength and direction of relationships between environmental compliance, waste management, land rehabilitation, environmental monitoring, and the sustainability of mining projects in Nyarugenge District.

Table 10 Correlations Coefficient Analysis Results for staff Respondents

|                    |                              |                                | Environmenta<br>l Compliance | Waste<br>Managemen<br>t | Land<br>Rehabilitatio<br>n | Environmenta<br>l Monitoring | Environmenta<br>l Quality<br>Management<br>Practices | Sustainabilit<br>y of Mining<br>Projects |
|--------------------|------------------------------|--------------------------------|------------------------------|-------------------------|----------------------------|------------------------------|------------------------------------------------------|------------------------------------------|
| Spearman'<br>s rho | Environmenta<br>l Compliance | Correlatio<br>n<br>Coefficient |                              |                         |                            |                              |                                                      |                                          |
|                    |                              | Sig. (2-<br>tailed)            |                              |                         |                            |                              |                                                      |                                          |
|                    |                              | N                              |                              |                         |                            |                              |                                                      |                                          |
|                    | Waste<br>Management          | Correlatio<br>n<br>Coefficient | .744**                       | 1.000                   |                            |                              |                                                      |                                          |
|                    |                              | Sig. (2-<br>tailed)            | .000                         | .                       |                            |                              |                                                      |                                          |
|                    |                              | N                              | 119                          | 119                     |                            |                              |                                                      |                                          |
|                    | Land<br>Rehabilitation       | Correlatio<br>n<br>Coefficient | .854**                       | .649**                  | 1.000                      |                              |                                                      |                                          |
|                    |                              | Sig. (2-<br>tailed)            | .000                         | .000                    | .                          |                              |                                                      |                                          |
|                    |                              | N                              | 119                          | 119                     | 119                        |                              |                                                      |                                          |
|                    | Environmenta<br>l Monitoring | Correlatio<br>n<br>Coefficient | .724**                       | .985**                  | .644**                     | 1.000                        |                                                      |                                          |
|                    |                              | Sig. (2-<br>tailed)            | .000                         | .000                    | .000                       | .                            |                                                      |                                          |
|                    |                              | N                              | 119                          | 119                     | 119                        | 119                          |                                                      |                                          |
|                    | Environmenta<br>l Quality    | Correlatio<br>n<br>Coefficient | .938**                       | .890**                  | .818**                     | .879**                       | 1.000                                                |                                          |

|  |                                   |                         |        |        |        |        |        |       |
|--|-----------------------------------|-------------------------|--------|--------|--------|--------|--------|-------|
|  | Management Practices              | Sig. (2-tailed)         | .000   | .000   | .000   | .000   | .      |       |
|  |                                   | N                       | 119    | 119    | 119    | 119    | 119    |       |
|  | Sustainability of Mining Projects | Correlation Coefficient | .949** | .796** | .854** | .812** | .955** | 1.000 |
|  |                                   | Sig. (2-tailed)         | .000   | .000   | .000   | .000   | .000   | .     |
|  |                                   | N                       | 119    | 119    | 119    | 119    | 119    | 119   |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The findings reveal a strong positive relationship between environmental compliance and sustainability of mining projects ( $r = 0.949$ ,  $p < 0.001$ ). This indicates that higher levels of compliance with environmental regulations are associated with greater sustainability of mining projects. Environmental compliance also exhibited strong positive correlations with environmental quality management practices ( $r = 0.938$ ), land rehabilitation ( $r = 0.854$ ), waste management ( $r = 0.744$ ), and environmental monitoring ( $r = 0.724$ ), implying that compliance is closely integrated with other environmental management initiatives.

Waste management was found to have a strong positive relationship with sustainability of mining projects ( $r = 0.796$ ,  $p < 0.001$ ), indicating that effective waste management practices contribute significantly to the long-term sustainability of mining operations. Furthermore, waste management was strongly correlated with environmental monitoring ( $r = 0.985$ ), environmental quality management practices ( $r = 0.890$ ), environmental compliance ( $r = 0.744$ ), and land rehabilitation ( $r = 0.649$ ), demonstrating that effective waste management is closely linked with broader environmental management strategies.

The analysis further shows that land rehabilitation had a strong positive and statistically significant relationship with sustainability of mining projects ( $r = 0.854$ ,  $p < 0.001$ ). This finding suggests that restoring mined land contributes substantially to sustainable mining outcomes. Land rehabilitation also showed strong positive relationships with environmental quality management practices ( $r = 0.818$ ),

environmental compliance ( $r = 0.854$ ), environmental monitoring ( $r = 0.644$ ), and waste management ( $r = 0.649$ ). Similarly, environmental monitoring demonstrated a strong positive relationship with sustainability of mining projects ( $r = 0.812$ ,  $p < 0.001$ ). This implies that continuous monitoring of environmental conditions supports the sustainable implementation of mining projects. Environmental monitoring was also strongly associated with environmental quality management practices ( $r = 0.879$ ), waste management ( $r = 0.985$ ), environmental compliance ( $r = 0.724$ ), and land rehabilitation ( $r = 0.644$ ), indicating that monitoring is an essential component of integrated environmental management.

Environmental quality management practices exhibited the strongest positive association with sustainability of mining projects ( $r = 0.955$ ,  $p < 0.001$ ). This finding suggests that comprehensive environmental quality management practices are highly associated with improved sustainability outcomes in mining projects. Additionally, environmental quality management practices maintained strong positive correlations with environmental compliance ( $r = 0.938$ ), waste management ( $r = 0.890$ ), environmental monitoring ( $r = 0.879$ ), and land rehabilitation ( $r = 0.818$ ), reflecting the interconnected nature of environmental management dimensions. The strong positive correlation coefficients, ranging from  $r = 0.796$  to  $r = 0.955$  between the independent variables and sustainability, indicate that strengthening environmental compliance, waste management, land rehabilitation, environmental monitoring, and overall environmental quality management practices is associated with enhanced sustainability of mining projects.

Table 11 Correlation Coefficient Analysis Matrix for Community Respondents near Mining Sites

|                |                          |                         | Environmental Compliance | Waste Management | Land Rehabilitation | Environmental Monitoring | Environmental Quality Management Practices | Sustainability of Mining Projects |
|----------------|--------------------------|-------------------------|--------------------------|------------------|---------------------|--------------------------|--------------------------------------------|-----------------------------------|
| Spearman's rho | Environmental Compliance | Correlation Coefficient | 1.000                    |                  |                     |                          |                                            |                                   |
|                |                          | Sig. (2-tailed)         | .                        |                  |                     |                          |                                            |                                   |
|                |                          | N                       | 96                       |                  |                     |                          |                                            |                                   |
|                | Waste Management         | Correlation Coefficient | .743**                   | 1.000            |                     |                          |                                            |                                   |
|                |                          | Sig. (2-tailed)         | .000                     | .                |                     |                          |                                            |                                   |
|                |                          | N                       | 96                       | 96               |                     |                          |                                            |                                   |

|  |                                            |                         |        |        |        |        |        |       |
|--|--------------------------------------------|-------------------------|--------|--------|--------|--------|--------|-------|
|  | Land Rehabilitation                        | Correlation Coefficient | .971** | .718** | 1.000  |        |        |       |
|  |                                            | Sig. (2-tailed)         | .000   | .000   | .      |        |        |       |
|  |                                            | N                       | 96     | 96     | 96     |        |        |       |
|  | Environmental Monitoring                   | Correlation Coefficient | .767** | .932** | .761** | 1.000  |        |       |
|  |                                            | Sig. (2-tailed)         | .000   | .000   | .000   | .      |        |       |
|  |                                            | N                       | 96     | 96     | 96     | 96     |        |       |
|  | Environmental Quality Management Practices | Correlation Coefficient | .937** | .873** | .944** | .894** | 1.000  |       |
|  |                                            | Sig. (2-tailed)         | .000   | .000   | .000   | .000   | .      |       |
|  |                                            | N                       | 96     | 96     | 96     | 96     | 96     |       |
|  | Sustainability of Mining Projects          | Correlation Coefficient | .879** | .787** | .871** | .758** | .891** | 1.000 |
|  |                                            | Sig. (2-tailed)         | .000   | .000   | .000   | .000   | .000   | .     |
|  |                                            | N                       | 96     | 96     | 96     | 96     | 96     | 96    |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The results indicate that environmental compliance has a strong and significant positive relationship with sustainability ( $r = 0.879$ ,  $p = 0.000$ ,  $N = 96$ ). Waste management also shows a strong positive relationship ( $r = 0.787$ ,  $p = 0.000$ ,  $N = 96$ ), while land rehabilitation demonstrates a similarly strong association ( $r = 0.871$ ,  $p = 0.000$ ,  $N = 96$ ). Environmental monitoring shows a positive and significant relationship with sustainability ( $r = 0.758$ ,  $p = 0.000$ ,  $N = 96$ ), while the composite variable of environmental quality management practices shows a very strong correlation ( $r = 0.891$ ,  $p = 0.000$ ,  $N = 96$ ). Overall, the results confirm that all environmental

management dimensions are positively and significantly associated with the sustainability of mining projects.

#### ➤ Multiple Linear Regression Analysis

To determine the extent to which environmental quality management practices influence the sustainability of mining projects, a multiple linear regression analysis was conducted. This technique was applied to assess the combined and individual predictive power of environmental compliance, waste management, land rehabilitation, environmental monitoring, and the sustainability of mining projects in Nyarugenge District.

Table 12 Model Summary<sup>b</sup> for Staff Respondents

| Model                                                                                                                | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|----------------------------------------------------------------------------------------------------------------------|-------------------|----------|-------------------|----------------------------|---------------|
| 1                                                                                                                    | .916 <sup>a</sup> | .838     | .833              | 3.02736                    | 1.878         |
| a. Predictors: (Constant), Environmental Monitoring, Land Rehabilitation, Environmental Compliance, Waste Management |                   |          |                   |                            |               |
| b. Dependent Variable: Sustainability of Mining Projects (Dependent Variable)                                        |                   |          |                   |                            |               |

The results indicate that the regression model provides a strong fit to the data. The model produced a multiple correlation coefficient (R) of 0.916, indicating a very strong positive relationship between the combined predictor variables and the sustainability of mining projects. The coefficient of determination ( $R^2$ ) was 0.838, implying that 83.8% of the variation in the sustainability of mining projects is explained by the combined effects of environmental compliance, waste management, land rehabilitation, and environmental monitoring.

The adjusted  $R^2$  value of 0.833 further confirms the robustness of the regression model. After adjusting for the

number of predictor variables included in the analysis, the model still explains 83.3% of the variance in the sustainability of mining projects. The small difference between  $R^2$  (0.838) and adjusted  $R^2$  (0.833) suggests that the predictor variables make meaningful contributions to the model and that the model is not substantially affected by overfitting.

The Durbin–Watson statistic was 1.878, which is close to the ideal value of 2.0. This suggests that there is no significant autocorrelation among the residuals, indicating that the assumption of independence of errors has been satisfied. Consequently, the regression estimates can be considered reliable for inference.

Table 13 Model Summary<sup>b</sup> for Community Respondents near Mining Sites,

| Model                                                                                                                | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics |          |     |     |               | Durbin-Watson |
|----------------------------------------------------------------------------------------------------------------------|-------------------|----------|-------------------|----------------------------|-------------------|----------|-----|-----|---------------|---------------|
|                                                                                                                      |                   |          |                   |                            | R Square Change   | F Change | df1 | df2 | Sig. F Change |               |
| 1                                                                                                                    | .897 <sup>a</sup> | .805     | .797              | 3.42560                    | .805              | 94.039   | 4   | 91  | .000          | 2.195         |
| a. Predictors: (Constant), Environmental Monitoring, Environmental Compliance, Waste Management, Land Rehabilitation |                   |          |                   |                            |                   |          |     |     |               |               |
| b. Dependent Variable: Sustainability of Mining Projects (Dependent Variable)                                        |                   |          |                   |                            |                   |          |     |     |               |               |

The model shows an R value of 0.897, indicating a strong relationship between predictors and the dependent variable. The R-square value of 0.805 shows that 80.5% of the variation in sustainability of mining projects is explained by environmental compliance, waste management, land rehabilitation, and environmental monitoring. The adjusted R-square value of 0.797 confirms the robustness of the model after adjustment for sample size and predictors. The standard error of the estimate is 3.42560, and the Durbin-Watson statistic of 2.195 indicates no serious autocorrelation problems in the model.

Table 14 ANOVA<sup>a</sup> for staff Respondents

| Model                                                                                                                |            | Sum of Squares | df  | Mean Square | F       | Sig.              |
|----------------------------------------------------------------------------------------------------------------------|------------|----------------|-----|-------------|---------|-------------------|
| 1                                                                                                                    | Regression | 5420.189       | 4   | 1355.047    | 147.851 | .000 <sup>b</sup> |
|                                                                                                                      | Residual   | 1044.803       | 114 | 9.165       |         |                   |
|                                                                                                                      | Total      | 6464.992       | 118 |             |         |                   |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable)                                        |            |                |     |             |         |                   |
| b. Predictors: (Constant), Environmental Monitoring, Land Rehabilitation, Environmental Compliance, Waste Management |            |                |     |             |         |                   |

The results indicate that the regression model is statistically significant, with an F-statistic of 147.851 and a corresponding significance value of  $p < 0.001$ . This demonstrates that the combined effect of environmental compliance, waste management, land rehabilitation, and environmental monitoring significantly predicts the sustainability of mining projects. Since the significance value is less than the conventional threshold of 0.05, the null hypothesis that the predictor variables have no joint effect on the sustainability of mining projects is rejected. The regression model accounted for a regression sum of squares of 5420.189 with 4 degrees of freedom, resulting in a mean square regression of 1355.047. In comparison, the residual sum of

squares was 1044.803 with 114 degrees of freedom, producing a mean square residual of 9.165. The substantially larger regression mean square relative to the residual mean square explains the high F-value obtained, indicating that the model explains a significant proportion of the variation in the sustainability of mining projects beyond what would be expected by chance. The total sum of squares was 6464.992, representing the overall variation in the sustainability of mining projects. Of this total variation, a substantial proportion was explained by the regression model, confirming that the selected environmental management variables collectively contribute significantly to explaining differences in the sustainability of mining projects.

Table 15 ANOVA<sup>a</sup> for Community Respondents Near Mining Sites,

| Model                                                                                                                |            | Sum of Squares | df | Mean Square | F      | Sig.              |
|----------------------------------------------------------------------------------------------------------------------|------------|----------------|----|-------------|--------|-------------------|
| 1                                                                                                                    | Regression | 4414.096       | 4  | 1103.524    | 94.039 | .000 <sup>b</sup> |
|                                                                                                                      | Residual   | 1067.863       | 91 | 11.735      |        |                   |
|                                                                                                                      | Total      | 5481.958       | 95 |             |        |                   |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable)                                        |            |                |    |             |        |                   |
| b. Predictors: (Constant), Environmental Monitoring, Environmental Compliance, Waste Management, Land Rehabilitation |            |                |    |             |        |                   |

The ANOVA results further confirm the model's significance, with an F-value of 94.039 and significance level of 0.000, indicating that the regression model is statistically significant.

Table 16 Regression Coefficients<sup>a</sup> for staff Respondents

| Model                                                                         |                          | Unstandardized Coefficients |            | Standardized Coefficients | t     | Sig. | 95.0% Confidence Interval for B |             | Collinearity Statistics |         |
|-------------------------------------------------------------------------------|--------------------------|-----------------------------|------------|---------------------------|-------|------|---------------------------------|-------------|-------------------------|---------|
|                                                                               |                          | B                           | Std. Error |                           |       |      | Lower Bound                     | Upper Bound | Tolerance               | VIF     |
| 1                                                                             | (Constant)               | 14.547                      | 2.688      |                           | 5.412 | .000 | 9.222                           | 19.871      |                         |         |
|                                                                               | Environmental Compliance | 2.803                       | .334       | .806                      | 8.386 | .000 | 2.141                           | 3.465       | .153                    | 6.520   |
|                                                                               | Waste Management         | 4.441                       | 1.577      | 1.228                     | 2.817 | .006 | 7.564                           | 1.318       | .007                    | 133.934 |
|                                                                               | Land Rehabilitation      | .047                        | .260       | .013                      | .180  | .000 | .563                            | .469        | .255                    | 3.925   |
|                                                                               | Environmental Monitoring | 4.932                       | 1.542      | 1.363                     | 3.199 | .002 | 1.878                           | 7.986       | .008                    | 128.105 |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable) |                          |                             |            |                           |       |      |                                 |             |                         |         |

The regression constant was 14.547, indicating that when all environmental management practices are assumed to be zero, the predicted level of sustainability of mining projects would be 14.547 units. However, the significant contribution of the predictor variables demonstrates that improvements in environmental management practices are associated with increased sustainability outcomes.

The results indicate that environmental compliance has a positive and statistically significant effect on the sustainability of mining projects ( $B = 2.803$ ,  $\beta = 0.806$ ,  $p < 0.001$ ). This means that a one-unit increase in environmental compliance is expected to increase the sustainability of mining projects by approximately 2.803 units, assuming that waste management, land rehabilitation, and environmental monitoring remain unchanged.

Waste management also showed a positive and statistically significant effect on the sustainability of mining projects ( $B = 4.441$ ,  $\beta = 1.228$ ,  $p = 0.006$ ). The coefficient indicates that a one-unit improvement in waste management practices would result in an estimated increase of 4.441 units in the sustainability of mining projects, holding another factors constant.

Land rehabilitation demonstrated a positive but statistically insignificant relationship with the sustainability of mining projects ( $B = 0.047$ ,  $\beta = 0.013$ ,  $p < 0.001$ ). The coefficient indicates that a one-unit increase in land rehabilitation practices would increase sustainability by approximately 0.047 units when other variables are controlled.

Environmental monitoring recorded a positive and statistically significant effect on the sustainability of mining projects ( $B = 4.932$ ,  $\beta = 1.363$ ,  $p = 0.002$ ).

Comparatively, based on the standardized coefficients (Beta values), environmental monitoring ( $\beta = 1.363$ ) and waste management ( $\beta = 1.228$ ) appear to have the strongest relative influence on the sustainability of mining projects, followed by environmental compliance ( $\beta = 0.806$ ), while land rehabilitation has the weakest relative contribution ( $\beta = 0.013$ ).

The regression equation derived from the unstandardized coefficients can therefore be expressed as: Sustainability of Mining Projects =  $14.547 + 2.803 (x_1) + 4.441(x_2) + 0.047(x_3) + 4.932(x_4)$

This equation implies that, while keeping other factors constant, every one-unit improvement in environmental compliance, waste management, land rehabilitation, and environmental monitoring increases the predicted sustainability of mining projects by 2.803, 4.441, 0.047, and 4.932 units respectively.

The collinearity statistics show that some predictors have high Variance Inflation Factor (VIF) values, particularly waste management ( $VIF = 133.934$ ) and environmental monitoring ( $VIF = 128.105$ ), indicating possible multicollinearity among the independent variables.

Table 17 Regression Coefficients<sup>a</sup> for Community Respondents near Mining Sites,

| Model                                                                         | Unstandardized Coefficients |            | Standardized Coefficients | t     | Sig.  | 95.0% Confidence Interval for B |             | Correlations |         |      | Collinearity Statistics |        |
|-------------------------------------------------------------------------------|-----------------------------|------------|---------------------------|-------|-------|---------------------------------|-------------|--------------|---------|------|-------------------------|--------|
|                                                                               | B                           | Std. Error |                           |       |       | Lower Bound                     | Upper Bound | Zero-order   | Partial | Part | Tolerance               | VIF    |
| 1                                                                             | (Constant)                  | 11.727     | 3.413                     | 3.436 | .001  | 4.948                           | 18.505      |              |         |      |                         |        |
|                                                                               | Environmental Compliance    | .772       | .956                      | .210  | .808  | 1.127                           | 2.671       | .880         | .084    | .037 | .032                    | 31.628 |
|                                                                               | Waste Management            | 2.414      | .765                      | .636  | 3.157 | .895                            | 3.933       | .819         | .314    | .146 | .053                    | 18.964 |
|                                                                               | Land Rehabilitation         | 2.040      | .960                      | .552  | 2.124 | .132                            | 3.948       | .880         | .217    | .098 | .032                    | 31.600 |
|                                                                               | Environmental Monitoring    | 1.819      | .799                      | .483  | 2.275 | 3.406                           | .231        | .800         | .232    | .105 | .048                    | 21.029 |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable) |                             |            |                           |       |       |                                 |             |              |         |      |                         |        |

The regression coefficients reveal the individual contribution of each predictor to sustainability. Environmental compliance has a coefficient of 0.772 ( $B = 0.772$ ,  $SE = 0.956$ ,  $Beta = 0.210$ ,  $t = 0.808$ ,  $Sig. = 0.421$ ), indicating a positive but statistically insignificant effect. Waste management shows a significant positive effect on sustainability with  $B = 2.414$ ,  $SE = 0.765$ ,  $Beta = 0.636$ ,  $t = 3.157$ ,  $Sig. = 0.002$ , confirming its strong contribution. Land rehabilitation also has a significant

positive effect with  $B = 2.040$ ,  $SE = 0.960$ ,  $Beta = 0.552$ ,  $t = 2.124$ ,  $Sig. = 0.036$ , indicating that it contributes meaningfully to sustainability outcomes. Environmental monitoring shows a statistically significant positive effect with  $B = 1.819$ ,  $SE = 0.799$ ,  $Beta = 0.483$ ,  $t = 2.275$ ,  $Sig. = 0.025$ , confirming its influence on sustainability. The constant term is 11.727 ( $SE = 3.413$ ,  $t = 3.436$ ,  $Sig. = 0.001$ ), representing the baseline level of sustainability when all predictors are zero.

Table 18 Collinearity Diagnostics<sup>a</sup> for Staff Respondents

| Model                                                                         | Dimension | Eigenvalue | Condition Index | Variance Proportions |                          |                  |                     |                          |
|-------------------------------------------------------------------------------|-----------|------------|-----------------|----------------------|--------------------------|------------------|---------------------|--------------------------|
|                                                                               |           |            |                 | (Constant)           | Environmental Compliance | Waste Management | Land Rehabilitation | Environmental Monitoring |
| 1                                                                             | 1         | 4.986      | 1.000           | .00                  | .00                      | .00              | .00                 | .00                      |
|                                                                               | 2         | .009       | 24.000          | .98                  | .02                      | .00              | .01                 | .00                      |
|                                                                               | 3         | .003       | 38.556          | .00                  | .02                      | .01              | .53                 | .01                      |
|                                                                               | 4         | .001       | 58.275          | .02                  | .93                      | .00              | .44                 | .00                      |
|                                                                               | 5         | 4.382E-005 | 337.335         | .00                  | .04                      | .99              | .02                 | .99                      |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable) |           |            |                 |                      |                          |                  |                     |                          |

The analysis examined the eigenvalues, condition indices, and variance proportions for environmental compliance, waste management, land rehabilitation, and environmental monitoring. The results show that the model has varying levels of collinearity among the predictor variables. The condition indices provide an indication of possible multicollinearity, where values above 30 generally suggest the presence of serious collinearity problems. In this analysis, the condition indices increased across the dimensions, with the highest value recorded in Dimension 5 (337.335), indicating a strong potential for multicollinearity among some of the independent variables.

In Dimension 2, the condition index was 24.000, with the constant accounting for 98% of the variance proportion. This indicates that the constant term contributes substantially to the variance at this dimension, although the level of collinearity among the independent variables remains relatively limited at this stage.

Dimension 3 recorded a condition index of 38.556, exceeding the recommended threshold of 30. At this level, land rehabilitation accounted for 53% of the variance proportion, while the other predictor variables contributed smaller proportions. Dimension 4 produced a condition index of 58.275, indicating a stronger level of collinearity. At this dimension, environmental compliance accounted for 93% of the variance proportion, while land rehabilitation contributed 44%. This suggests that environmental compliance and land rehabilitation have some degree of overlap in explaining variations in the sustainability of mining projects. The most critical indication of multicollinearity was observed in Dimension 5, where the condition index reached 337.335. At this dimension, waste management accounted for 99% of the variance proportion, while environmental monitoring also accounted for 99%.

Table 19 Collinearity Diagnostics<sup>a</sup> for Community Respondents near Mining Sites,

| Model                                                                         | Dimension | Eigenvalue | Condition Index | Variance Proportions |                          |                  |                     |                          |
|-------------------------------------------------------------------------------|-----------|------------|-----------------|----------------------|--------------------------|------------------|---------------------|--------------------------|
|                                                                               |           |            |                 | (Constant)           | Environmental Compliance | Waste Management | Land Rehabilitation | Environmental Monitoring |
| 1                                                                             | 1         | 4.988      | 1.000           | .00                  | .00                      | .00              | .00                 | .00                      |
|                                                                               | 2         | .009       | 24.125          | .97                  | .00                      | .00              | .00                 | .00                      |
|                                                                               | 3         | .003       | 41.808          | .02                  | .03                      | .06              | .03                 | .04                      |
|                                                                               | 4         | .000       | 122.261         | .00                  | .11                      | .67              | .08                 | .70                      |
|                                                                               | 5         | .000       | 166.297         | .00                  | .85                      | .27              | .88                 | .26                      |
| a. Dependent Variable: Sustainability of Mining Projects (Dependent Variable) |           |            |                 |                      |                          |                  |                     |                          |

To ensure the reliability of regression results, multicollinearity was assessed using tolerance and VIF values. The results show that environmental compliance has a tolerance value associated with a VIF of 31.628, waste management has a VIF of 18.964, land rehabilitation has a VIF of 31.600, and environmental monitoring has a VIF of 21.029. The condition index values range from 1.000 to 166.297, indicating the presence of multicollinearity among predictors, particularly in higher dimensions where values exceed conventional thresholds. The regression model remains statistically significant, although the presence of multicollinearity suggests that caution should be taken when interpreting individual predictor effects. In summary, the inferential analysis demonstrates that environmental quality management practices collectively have a strong and statistically significant influence on the sustainability of mining projects in Nyarugenge District. The model explains a substantial proportion of variance (80.5%), confirming strong

predictive power. While all variables show positive relationships with sustainability, waste management, land rehabilitation, and environmental monitoring emerge as statistically significant predictors, whereas environmental compliance shows a positive but non-significant effect.

## V. CONCLUSIONS AND RECOMMENDATIONS

### ➤ Conclusions

The study concludes that environmental quality management plays a vital role in enhancing the sustainability of mining projects in Nyarugenge District. The findings demonstrate that mining companies achieve better environmental and operational performance when they effectively implement environmental management practices. Although all four environmental quality management dimensions were positively associated with sustainability, waste management, land rehabilitation, and environmental

monitoring were identified as the most influential determinants. These findings suggest that sustainable mining requires not only compliance with environmental regulations but also the consistent implementation of practical environmental management interventions.

The study concludes that environmental compliance provides an essential legal and institutional foundation for sustainable mining operations. Mining companies generally comply with environmental regulations through environmental permitting, Environmental Impact Assessments, and adherence to national standards. However, compliance alone does not guarantee sustainable mining outcomes. Organizations should therefore complement regulatory compliance with proactive environmental management practices to achieve long-term sustainability.

Waste management was identified as the strongest determinant of mining project sustainability. Effective waste segregation, treatment, disposal, recycling, and pollution prevention contribute significantly to environmental protection, public health, operational efficiency, and long-term project performance. Continuous improvement of waste management systems should therefore remain a strategic priority for mining companies.

#### ➤ Recommendations

Mining companies should strengthen integrated environmental management systems by investing in effective waste management technologies, timely land rehabilitation programmes, continuous environmental monitoring, and staff capacity development. Adequate financial resources should be allocated to environmental conservation activities, supported by regular environmental performance evaluations to promote continuous improvement.

RMB should strengthen environmental supervision through regular inspections, compliance audits, technical guidance, and enforcement of environmental regulations. The Board should also encourage mining companies to adopt internationally recognized environmental management standards and sustainable mining technologies.

REMA should continue strengthening environmental regulation enforcement through periodic environmental audits, monitoring compliance with Environmental Impact Assessment recommendations, and providing technical support and environmental education programmes. Greater collaboration between mining companies and surrounding communities should also be encouraged to improve environmental stewardship.

The District administration should strengthen environmental governance by working closely with mining companies, REMA, RMB, and local communities to monitor environmental performance. Community environmental committees and awareness programmes should be supported to encourage public participation in environmental conservation.

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