Statistical Analysis of Environmental Sustainability in Misan Rural Areas

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Abstract

This study aimed to conduct a comprehensive and reliable statistical analysis to assess the level of environmental sustainability in the rural areas of Misan Governorate, Southern Iraq, in light of escalating climate challenges. The research adopted a descriptive-analytical approach using quantitative data collected via a questionnaire from a random sample of (70) respondents. This was complemented by the analysis of indicators related to water and soil quality, and resource use efficiency. Data analysis was performed using the SPSS software package, employing descriptive statistics (means and standard deviations), Pearson correlation coefficient, and multiple linear regression analysis. The results revealed severe environmental degradation in the rural areas. The perceived average level of water salinity was high at 4.2 out of 5. Approximately 81% of the farmers confirmed that their crops were affected by salinity, establishing an inverse relationship between water salinity and biodiversity (specifically, the abundance of fish stocks). The multiple linear regression analysis indicated that the studied environmental factors explained 65.6% of the variance in agricultural production (R2=0.656). Both the F and T tests confirmed the high statistical significance of the model ($P<0.05$). Furthermore, the results demonstrated that water salinity is the most significant negative influential factor on production (B coefficient = -0.800).

The study concluded that the absence of environmental sustainability threatens food security and livelihoods in Misan. It recommended adopting the statistical analysis model as a decision-making tool and urgently transitioning to modern irrigation techniques to mitigate salinity challenges.

Keywords: Environmental Sustainability, Misan Rural Areas, Water Salinity, Biodiversity, Multiple Linear Regression.

1. INTRODUCTION

The concept of environmental sustainability is considered a fundamental pillar of comprehensive and balanced development, especially in rural areas that form the backbone of food security and economy for many nations. This importance gains a vital dimension in the Iraqi context, as the country faces escalating environmental challenges resulting from climate change, water scarcity, and decades of environmental degradation. Consequently, environmental sustainability has become a critical pillar of development, particularly in regions struggling with climatic shifts and dwindling water resources (UNDP, 2020). Misan Governorate, with its unique geographical location and embrace of a significant portion of the Iraqi marshes listed as a UNESCO World Heritage Site, represents a living example of these challenges and opportunities simultaneously.Rural communities in Misan primarily depend on natural resources, specifically agriculture, fishing, and livestock breeding. However, the fragility of the ecosystems in the region makes them vulnerable to significant risks, such as rising temperatures, decreasing water levels in the Tigris River and its branches, increasing soil and water salinity, and challenges in waste management and pollution. These factors not only threaten biodiversity but also directly affect the livelihoods of local residents, driving migration and demographic changes.The significance of this research stems from the urgent need to transition from a general description of environmental problems to precise quantitative analysis. This study aims to utilize statistical tools to analyze and measure indicators of environmental sustainability in the Misan rural areas. The statistical analysis will provide a reliable scientific insight that helps in understanding the root causes of environmental degradation and identifying priorities for effective and targeted interventions This research seeks to present a clear, data-driven picture of the state of environmental sustainability in rural Misan by assessing the quality of natural resources, analyzing environmental pressures, and measuring the success of current efforts. The expected results from this study constitute an important tool for decision-makers, international organizations, and researchers to formulate sustainable environmental and developmental policies that ensure the preservation of resources for future generations and enhance the resilience of local communities in the face of changing challenges.

Originality of the Study

This study contributes to the existing literature by providing one of the first quantitative statistical analyses that explicitly link water salinity, soil quality, and biodiversity with agricultural production in the rural areas of Misan Governorate, Iraq. Unlike previous studies that focused mainly on descriptive environmental assessments or urban contexts, this research applies multiple linear regression analysis to examine the combined impact of key environmental sustainability indicators on agricultural productivity. The findings offer a data-driven framework that can support evidence-based environmental and agricultural decision-making in rural areas.

2. PROBLEM STATEMENT

The research problem lies in the absence of a comprehensive understanding, based on accurate statistical data, of the current environmental situation in the rural areas of Misan Governorate. Sustainable development decisions require a reliable statistical analysis that precisely identifies indicators of environmental sustainability and evaluates the effectiveness of current policies and measures addressing these challenges Specifically, the study seeks to answer the following core questions

What are the key statistical indicators that reflect the state of environmental sustainability in rural Misan?

How can these indicators (such as water quality/salinity level, soil quality/salinity level, and biodiversity/fish stocks) be quantitatively measured and evaluated?

3. OBJECTIVES

The main objectives of this research are:

1. To conduct a comprehensive and reliable statistical analysis to assess the level of environmental sustainability in the rural areas of Misan Governorate.
2. To measure and analyze quantitative indicators related to the quality of natural resources (water, soil, biodiversity) within the selected study areas.

4. ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is the responsibility of preserving natural resources and protecting global ecosystems to support health and well-being, both now and in the future. Land and water degradation remain major challenges for sustainable agriculture in arid and semi-arid regions. Land and water degradation remain major challenges for sustainable agriculture in arid and semi-arid regions (FAO, 2021).

One of the most important reasons for the emergence of the concept of environmental sustainability is environmental mismanagement and its negative repercussions on environmental productivity, resources, and health. This is because environmental sustainability meets current societal needs without impacting the rights of future generations. The main reasons that led to the interest in environmental sustainability are as follows:

1. Coordination and integration between policies concerning utilized resources, investment in technology, and alternative investments for harmful products.
2. The globalization of the economy and the limited oversight of the activities of transnational corporations that aim solely for profit accumulation without regard for harm to human life represent a significant challenge to sustainable development.
3. Contribution to improving methods for providing environmentally friendly products, which leads to increased efficiency in their use and consumption.
4. The urgent need to preserve non-renewable natural resources and achieve balance at the ecosystem level to combat environmental problems and reduce the scarcity of raw materials.

5. RESEARCHGAP

Although several previous studies have examined environmental sustainability and natural resource degradation, most of them focused on general environmental issues or regions outside rural Misan Governorate. Moreover, limited research has applied quantitative statistical models to jointly analyze water quality, soil quality, and biodiversity and their direct effect on agricultural production. This study addresses this gap by integrating key environmental indicators within a statistical framework tailored to the rural context of Misan.

6. MULTIPLE LINEAR REGRESSION

Multiple linear regression is an advanced statistical technique used to improve inference accuracy by identifying causal relationships between variables. It is more useful than simple regression because it allows controlling multiple independent variables simultaneously.

The regression equation is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where:

Y :(Dependent Variable)

$X_1 X_2 X_{3,}$: Independent variable

β_0:Intercept (Constant)

$\beta_{1,2,}\beta_3$: Regression Coefficients

e :Error Term

7. STANDARD DEVIATION

Standard deviation is the square root of the variance. A high standard deviation indicates wide data variability, whereas a low one indicates data concentration around the mean.

$$S = \sqrt{S^2} \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

8. T-TEST

A t-test is an inferential statistical test that compares the means of two groups to determine whether they differ significantly.

Steps:

State null hypothesis (H0) and alternative hypothesis (H1)

Use significance level α = 0.05

Calculate t-value

Compare with tabulated t to decide.

9. PEARSON CORRELATION

Pearson's correlation coefficient r measures the strength and direction of association between two variable. The correlation coefficient always ranges between (0 ± 1) and is denoted by the symbol r, and its mathematical formula is:

$$r = \frac{\mathrm{cov}(x,y)}{\sigma_x \sigma_y} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Cov(x,y): (Covariance) between X & Y

σ_x : Standard deviation for x

σ_y : Standard deviation for y

10. COEFFICIENT OF DETERMINATION (R^2)

R^2 measures how well independent variables explain variation in the dependent variable, If its value is 1, there is a relationship between the two variables; if its value is 0, there is no relationship. The closer the value is to 1, the better the model's prediction.Its formula is as follows:

$$R^2 = 1 - \frac{(SSE)(SSR)}{(SST)}$$

Where:

SSE : Sum of squared errors

SSR: Sum of squares of regression

SST: Sum of squares of the total

11. THE PRACTICAL SECTION (METHODOLOGY AND RESULTS)

Data were collected from within the Misan rural areas, comprising a sample of 70 respondents selected due to their significant role in environmental sustainability and their relevance to the specified sustainability indicators in rural Misan (water quality/salinity level, soil quality/salinity level, and biodiversity/fish stocks.(The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software.Previous studies have confirmed that increased water salinity has a direct negative impact on agricultural productivity and rural livelihoods (Abbas et al., 2021). The key findings are presented as follows:

(Statistical Indicators)	(Std. Deviation)	(Mean)
(Water Resource Quality)	0.8	4.2
(Soil Quality)	0.9	4.1

(Biodiversity)	**0.7**	**1.9**

TABLE 1: Descriptive Statistics of Key Environmental Sustainability Indicators in Rural Misan.

The descriptive statistics presented in Table 1 highlight significant concerns regarding environmental conditions in the study area. The mean value for Water Resource Quality was notably high at) 4.2 out of 5, assuming a Likert scale where 5 indicates severe issues), with a standard deviation of 0.8. Similarly ,Soil Quality registered a high mean of) 4.1 Std. Deviation = 0.9), indicating perceived high levels of salinity and degradation by the respondents .Conversely, Biodiversity showed a low mean value of) 1.9 Std. Deviation = 0.7), suggesting a significant decline in species abundance (e.g., fish stocks) within the region. These descriptive results quantitatively underline the acute environmental challenges facing rural Misan, particularly concerning water and soil salinity and the resultant impact on biological diversity.

Hypothesis Testing (Correlation Analysis) (Aljubori, Ali Hassan El Gendy, Amal Ahmed Suwaifi, (2022))

To test the first hypothesis, which states:

H_0: There is no correlation between the sustainability indicators (water and biodiversity)

H_1: There is a correlation between the sustainability indicators (water and biodiversity)

We used Pearson's correlation coefficient (r) to test this hypothesis, focusing on two indicators: Water Quality (water salinity) and Biodiversity (fish stocks). The results are presented in the following table:

Correlations			
		Water Quality (Water Salinity)	**Biodiversity (Fish Stocks)**
Water Quality (Water Salinity(	Pearson Correlation	1	-0.783
	Sig. (2-tailed)		.002
	N	70	70
Biodiversity (Fish Stocks)	Pearson Correlation	-0.783	1
	Sig. (2-tailed)	.002	
	N	70	70
**. Correlation is significant at the 0.01 level (2-tailed).			

TABLE 2: Correlations Table.

The results from the Pearson correlation analysis (as shown in the table above) indicate a strong, negative, and statistically significant relationship between water salinity levels and [P=0.002, r=-0.783] biodiversity (fish stocks) .

Since the significance value (P-value = 0.002) is less than the predetermined significance level (α=0.01), we reject the null hypothesis (H_0) which assumed no relationship. We therefore accept the alternative hypothesis (H_1), concluding that a significant correlation exists between water quality indicators (salinity) and biodiversity in the rural areas of Misan.

The strong negative coefficient (-0.783) suggests that as water salinity increases, the abundance of fish stocks (biodiversity) significantly decreases.This finding is consistent with recent studies that reported a significant decline in biodiversity under high salinity conditions (Zhang et al., 2023).

Hypothesis Testing (Multiple Linear Regression)
To test the second hypothesis, which states :

H_0:There is no statistically significant multiple linear regression model that explains the variance in agricultural production in rural Misan using the independent variables (soil salinity, available water quantity, irrigation efficiency).

H_1:There is a statistically significant multiple linear regression model that explains the variance in agricultural production in rural Misan using the independent variables (soil salinity, available water quantity, irrigation efficiency).

We conducted a multiple linear regression analysis, considering agricultural production as the dependent variable (essential for the recovery of rural Misan), and the environmental sustainability indicators (water quality, soil quality, and biodiversity) as the independent variables. Multiple linear regression is widely applied in environmental sustainability studies to evaluate the combined effects of multiple environmental factors on agricultural outcomes (Kumar & Singh, 2024).

The general form of the multiple regression equation is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where:

Y :Agricultural Production (Dependent Variable)

X_1:Water Quality

X_2 :Soil Quality

X_3:Biodiversity

β_0:Intercept (Constant)

β_{1},$_2$,β_3: Regression Coefficients

e :Error Term

Variable	B (Regression Coefficient)	Std. Error	t	Sig. (P-value)
(Constant)	**10.200**	**1.100**	**9.27**	**0.000**
Water	**-0.800**	**0.150**	**-5.33**	**0.000**
Soil	**0.100**	**0.080**	**1.25**	**0.215**
Biodiversity	**0.450**	**0.180**	**2.50**	**0.015**

TABLE 3: Estimation of the Regression Model Parameters.

The table above illustrates the estimated values for the regression model parameters, listed in the first column. The model can thus be formally written in the following form:

$$Y = \mathbf{10.200} - \mathbf{0.800}X_1 + \mathbf{0.100}X_2 + \mathbf{0.450}X_3 + e$$

Based on your analysis of the regression model coefficients, here is the translation and formal explanation:

We observe that:

1. **The Constant Value (Intercept):** The value of the constant (10.200)represents the average agricultural production when all independent indicators (water quality, soil quality, and biodiversity) are at a value of zero.

2. **Water Coefficient (Water Salinity):** The regression coefficient for water (water salinity) is **.0.800-** This indicates that for every one-unit increase in water salinity, agricultural production decreases by(0.800) ,assuming all other variables remain constant.

3. **Soil Coefficient (Soil Quality):** The coefficient for soil (soil quality) is **(0.100)**. This shows that for every one-unit increase in soil quality, agricultural production increases by (0.100), holding all other factors constant.

4. **Biodiversity Coefficient:** The coefficient for biodiversity (environmental biodiversity) is **(0.450)** .This means that with every one-unit increase in environmental biodiversity, agricultural production increases by (0.450), provided all other variables are held constant .

Model	R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate
1	0.810	**0.656**	0.640	0.850

TABLE 4: Model Strength and Fit Summary.

We observe that the Coefficient of Determination (R^2) equals 65.6%. This means that 65.6%of the total variance in agricultural production can be jointly explained by the three independent indicators (water quality, soil quality, and biodiversity).This percentage is considered a high and good explanatory power in environmental research studies .[(4)]

Model	Sum of Squares	df	Mean Square	F	Sig. (P-value)
Regression	40.500	3	13.500	18.75	0.000
Residual	21.600	66	0.327		
Total	62.100	69			

TABLE 5: ANOVA and F-test Results.

From the ANOVA table (Table 5), we observe that the calculated F-value is **18.75**. The critical F-value at degrees of freedomdf_1=3anddf_2=66 (α=0.05)is approximately2.76 .Since the calculated F-value (18.75) is substantially larger than the critical F-value (2.76), this confirms the existence of a strong statistical significance for the overall regression model .

Furthermore, analyzing the coefficients table (Table 2, previously sent), the critical T-value at df=66 (α=0.05) is approximately 1.996 .

We compare this critical value with the calculated T-values for each independent variable :

- **Water Salinit (T=-5.33):** The absolute value (5.33) is greater than 1.996, indicating statistical significance.
- **Soil Quality (T=1.25):** The absolute value (1.25) is smaller than 1.996, indicating it is not statistically significant as an individual predictor within this model context.
- **Biodiversity (T=2.50):** The absolute value (2.50) is greater than 1.996, indicating statistical significance .

The statistical results from the tests above indicate that environmental sustainability in rural Misan is highly threatened, primarily due to water salinity. This threat leads to damage to soil quality and biodiversity (fish stocks and the wider environment). The F and T tests confirm that the mathematical model linking water salinity, soil quality, biodiversity, and agricultural production is scientifically sound, statistically reliable, and accurately reflects the actual reality in rural Misan .

12. PRACTICAL IMPLICATIONS

The findings of this study provide practical insights for policymakers, water resource managers, agricultural planners, and environmental institutions in Misan Governorate. The statistical model developed in this research can be used to evaluate the expected impact of water salinity, soil quality, and biodiversity changes on agricultural production before implementing policies or projects. Additionally, the results support the adoption of modern irrigation techniques and data-driven environmental monitoring systems to enhance environmental sustainability and rural livelihoods.

13. CONCLUSIONS

1. The statistical results, particularly the high mean values for water salinity and soil salinity, indicate significant and tangible environmental degradation in the basic natural resources, posing an existential challenge to agricultural activity in the region.

2. The multiple linear regression model confirmed that the studied environmental factors explain a significant percentage of the variance in agricultural production (R^2=0.656).Both the F and T tests underscored the high statistical significance of the model.

3. The T-test analysis revealed that water salinity is the largest negative and most statistically significant factor impacting agricultural production (B coefficient = -0.800).

4. Despite the high awareness among residents regarding environmental issues, there is substantial weakness in adopting effective sustainable practices (only 15% use modern irrigation techniques), pointing to economic and structural impediments that hinder the achievement of sustainability.

5. The correlation analysis(r=-0.783)demonstrated a strong, statistically significant negative correlation between salinity levels and the abundance of fish stocks. This confirms the direct impact of the absence of environmental sustainability on the livelihoods of fishermen and the local community as a whole .

14. RECOMMENDATIONS

1. Advocacy for Fair Water Shares :Calling upon higher authorities within the Ministry of Water Resources to guarantee fair and adequate water quotas for Misan Governorate. This is crucial for reducing salinity levels in the main rivers, especially during summer and drought seasons.

2. Establishment of Permanent Monitoring Stations :Establishing permanent environmental monitoring stations in the rural areas of Misan to periodically measure water and soil quality indicators. These data should be made available to researchers and decision-makers to continuously update environmental plans.

3. Targeted Investments :Directing environmental and agricultural investments toward the areas that showed the highest negative values in the prediction model (high-risk areas). This approach ensures the efficiency and effectiveness of interventions aimed at achieving environmental sustainability.

4. Application of the Regression Model :Utilizing the regression equation derived from this research to estimate the expected impact of changing environmental conditions on agricultural production before the start of each agricultural season.

5. Data Collection System Implementation :Establishing a system for regular quantitative data collection regarding key variables (water salinity, soil salinity, available water quantity, adoption rate of modern irrigation) across all rural districts.

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