Bigint Computing Journal, Volume 3, Issue 1, January 2025, pp. 31-38

Bigint Computing Journal
Open Access
Publisher Ali Institute of Research and Publication

A Multi-Criteria Decision Support System for Prioritizing Forest and Land Rehabilitation Using MOORA and ORESTE

Sistem Pendukung Keputusan Multi-Kriteria untuk Memprioritaskan Rehabilitasi Hutan dan Lahan Menggunakan Metode MOORA dan ORESTE

Yustria Handika Siregar [1,*], Mohammad Badri [2], Nora Asyiqin [3], Syafhira Ananda Galasca[3], Fathur Rahman[3]

[1] Politeknis Cendana, Medan Indonesia
[2] Universitas Dinamika Bangsa, Jambi, Indonesia
[3] Universitas Islam Negeri Sumatera Utara, Medan, Indonesia

A B S T R A C T

This study integrates two analytical approaches, Multi-Objective Optimization by Ratio Analysis (MOORA) and Organization, Rangement Et Synthese De Donnes Relationnelles (ORESTE), to identify priority locations for forest and land rehabilitation in North Sumatra. The study evaluates six key criteria, including rehabilitation area size, carbon emissions, ecosystem degradation, biodiversity, rehabilitation potential, and environmental impact, across ten candidate sites. Initially, the MOORA method was applied to assess quantitative factors, revealing that the technical potential among the locations was nearly uniform. Subsequently, the ORESTE method was employed to evaluate qualitative factors, including community participation, socio-cultural values, and institutional support. This analysis revealed significant disparities in social readiness. For instance, South Tapanuli and Mandailing Natal emerged as top priorities due to their robust social support systems, while West Pakpak faced significant social challenges. This integrated approach offers a comprehensive framework that balances both technical and social dimensions for the successful implementation of sustainable forest rehabilitation programs.
Keyword: Decision Support System, Multi-Criteria, MOORA, ORESTE, Rehabilitation

A B S T R A K

Penelitian ini mengintegrasikan dua pendekatan analisis, Multi-Objective Optimization by Ratio Analysis (MOORA) dan Organization, Rangement Et Synthese De Donnes Relationnelles (ORESTE), untuk mengidentifikasi lokasi prioritas rehabilitasi hutan dan lahan di Sumatera Utara. Penelitian ini mengevaluasi enam kriteria utama, antara lain ukuran area rehabilitasi, emisi karbon, degradasi ekosistem, keanekaragaman hayati, potensi rehabilitasi, dan dampak lingkungan, pada sepuluh lokasi calon. Pada tahap awal, metode MOORA diterapkan untuk menilai faktor kuantitatif, yang mengungkapkan bahwa potensi teknis antar lokasi hampir seragam. Selanjutnya, metode ORESTE digunakan untuk mengevaluasi faktor kualitatif, termasuk partisipasi masyarakat, nilai-nilai sosial budaya, dan dukungan kelembagaan, yang mengungkapkan adanya disparitas signifikan dalam kesiapan sosial. Misalnya, wilayah Tapanuli Selatan dan Mandailing Natal muncul sebagai prioritas utama karena sistem dukungan sosial yang kuat, sedangkan Pakpak Barat menghadapi tantangan sosial yang signifikan. Pendekatan terintegrasi ini menawarkan kerangka kerja komprehensif yang menyeimbangkan dimensi teknis dan sosial guna mewujudkan keberhasilan implementasi program rehabilitasi hutan yang berkelanjutan.
Kata Kunci: Sistem Pendukung Keputusan, Multi-Kriteria, MOORA, ORESTE, Rehabilitasi

* Corresponding author:
Yustria Handika Siregar
Politeknis Cendana, Medan Indonesia
E-mail addresses: yustria.siregar@gmail.com
DOI: https://doi.org/10.55537/bigint.v3i1.1056
Received: 2025-01-24; Revised: 2025-02-02; Accepted: 2025-02-09

1. INTRODUCTION

Indonesia is a country with vast tropical forests, covering approximately 120.63 million hectares and serving as habitats for a high level of biodiversity [1], [2]. These forests provide valuable ecological, economic, and social benefits. However, activities such as illegal logging, land conversion for agriculture, and forest fires have led to widespread degradation [3]. This degradation has both local and global impacts, including increased greenhouse gas emissions, altered hydrological cycles, and threats to biodiversity [4], [5]. Forest and land rehabilitation is therefore a crucial solution to restore the functions of damaged ecosystems by integrating ecological, social, and economic aspects [6], [7].

In Indonesia, including North Sumatra Province, forest destruction and land degradation have reached critical levels due to deforestation, the conversion of land into oil palm plantations, and forest fires [8]-[11]. In addition to threatening the habitats of endemic flora and fauna, this degradation exacerbates climate change through high carbon emissions [12], [13]. One major challenge in forest rehabilitation is determining priority areas that require urgent intervention by considering factors such as the extent of ecosystem damage, costs, and potential socio-economic benefits [14]-[16], while the absence of a systematic approach hinders the achievement of optimal results [17].

Various methods have been employed in forest rehabilitation, but multi-criteria approaches are increasingly favored given the complexity of the issues involved [18], [19]. For example, the MOORA (Multi-Objective Optimization by Ratio Analysis) method has proven effective in managing quantitative criteria such as carbon emissions and rehabilitation costs, whereas the ORESTE (Order of Preference by Similarity to Ideal Solution) method is better suited for assessing qualitative criteria such as local community participation. Although these two methods have been applied separately in various studies, their combined application is still limited in Indonesia, even though previous research indicates that integrating these methods can result in more comprehensive and equitable decision-making [20]-[22].

This study aims to develop a decision support system that integrates the MOORA and ORESTE methods to determine the priority areas for forest and land rehabilitation in North Sumatra by incorporating ecological, social, and economic criteria in line with green economy principles [23], [24]. Consequently, it is expected that the rehabilitation process will be more efficient and sustainable, delivering tangible benefits to local communities and supporting environmental conservation. This integrated approach is particularly important because traditional rehabilitation methods that focus on a single aspect often overlook community needs and long-term sustainability [25]. MOORA excels in evaluating quantitative data [26], [27], while ORESTE effectively captures qualitative dimensions that are challenging to quantify numerically [28], [29]. The combination of these two methods in the decision support system offers a more adaptive approach to addressing the complexities and diverse needs of forest rehabilitation.

2. METHODOLOGY

This research employs a quantitative approach. This method follows solid, empirical, objective, measurable, rational, and systematic scientific principles. In a narrower scope, quantitative research is understood as research that heavily utilizes numbers throughout the data collection process, analysis, and presentation of results [30].

Problem Identification

The initial stage of this study begins by identifying the main problem, forest degradation and land degradation in North Sumatra, which have reached critical levels. Identification is done through the analysis of reports, government documents, and interviews with relevant stakeholders. The focus of the problem is the absence of a systematic approach to prioritize rehabilitation based on ecological, social, and economic criteria.

Literature Review

A literature review was conducted to understand existing approaches for prioritizing forest rehabilitation. The review covers the use of MOORA and ORESTE methods in various contexts, multi-criteria analysis, and green economy principles. This review aims to ensure that the methodology used in this research is relevant to the challenges faced [31].

Data Collection

Data were collected through field observations, interviews with stakeholders, and document analysis. The data collected includes information on forest damage levels, rehabilitation costs, potential socio-economic benefits, and local community participation. Data collection is performed to obtain a valid and comprehensive information base as input for the decision support system.

Analysis Stage

This stage involves data analysis to identify relevant criteria for determining priorities in forest rehabilitation. Quantitative data, such as ecosystem damage levels and costs, are analyzed using the MOORA method, while qualitative data, such as local community participation, are processed using the ORESTE method. The comparison of these two methods is used to determine priority areas that require immediate intervention.

Implementation of MOORA and ORESTE Methods

This study compares the MOORA (Multi-Objective Optimization by Ratio Analysis) and ORESTE (Organization, Rangement Et Synthese De Donnes Relationnelles) methods in the decision support system to prioritize forest and land rehabilitation. The methodology consists of the following stages:

1. MOORA (Multi-Objective Optimization by Ratio Analysis) Method

MOORA is a multi-criteria method used to optimize two or more conflicting criteria simultaneously. In this study, MOORA is applied to analyze quantitative criteria such as ecosystem damage, rehabilitation costs, and carbon absorption potential [32]. The stages of the MOORA method include:

Decision Matrix Formation

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

Where x_{ij} is the score of alternative i for criterion j, and the matrix has m alternatives and nn criteria.

Matrix Normalization

$$X_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_i x_{ij}^2}}$$

This normalizes the data so that values across different criteria can be compared and analyzed in a uniform way, regardless of their original scale.

Criteria Value Optimization

$$y_i = \sum_j w_j x_{ij} - \sum_j w_j x_{ij}$$

Where:

(i) yi is the total value for alternative i,
(ii) wj is the weight of criterion j,
(iii) xij is the normalized score of alternative ii for criterion j.

This step allows the alternatives to be ranked based on their overall performance across the different criteria.

2. ORESTE (Organization, Rangement Et Synthese De Donnes Relationnelles) Method

ORESTE is used to handle qualitative criteria such as local community participation, socio-cultural values, and institutional aspects [33]. The stages of the ORESTE method include:

Besson Projection

$$D(r,d) = \left[\frac{(r-1)^{\alpha} + (d-1)^{\alpha}}{2}\right]^{\frac{1}{\alpha}} + 1$$

Where:

(i) $D(r,d)$ is the distance between alternatives r and d,
(ii) α is a parameter that defines the level of influence for each distance.

This projection helps transform qualitative assessments into a form that can be used alongside the quantitative data from MOORA.

Global Score Aggregation

$$GS_i = \sum_j w_j B_{ij}$$

Where:

(i) GS_i is the global score for alternative i,
(ii) wj is the weight of criterion j,
(iii) Bij is the score of alternative i for criterion j after applying the Besson projection.

This step results in a global score for each alternative that reflects both the quantitative and qualitative criteria, allowing for a comprehensive evaluation.

These formulas and stages are essential for implementing the MOORA and ORESTE methods within the decision support system. MOORA handles quantitative criteria through matrix normalization and optimization, while ORESTE handles qualitative criteria using Besson's projection and global score aggregation. Together, they help prioritize the rehabilitation locations based on a balanced evaluation of both types of criteria.

3. RESULTS AND DISCUSSION

This study uses a combination approach of MOORA (Multi-Objective Optimization by Ratio Analysis) and ORESTE (Organization, Rangement Et Synthese De Donnes Relationnelles) methods to evaluate and prioritize forest rehabilitation sites in North Sumatra Province. The MOORA method is used to assess quantitative criteria such as the area of rehabilitation, carbon emissions, ecosystem degradation, biodiversity, rehabilitation potential, and environmental impact. Meanwhile, ORESTE is used to evaluate qualitative criteria such as community participation, socio-cultural values, and institutional aspects. The integration of these two methods provides a more comprehensive understanding, combining both technical and social aspects in decision-making.

Determination of Criteria Data

In this study, six criteria were used to evaluate each rehabilitation location alternative. The weights of the criteria were determined based on the relative importance of each criterion as follows:

Table 1. Criteria Data

Code	Criterion	Type
C1	Rehabilitation Area	Benefit
C2	Carbon Emissions	Cost
C3	Damage Level	Cost
C4	Biodiversity	Benefit
C5	Rehabilitation Potential	Cost
C6	Environmental Impact	Benefit

In this section, the criteria used in this study to evaluate rehabilitation locations are well-defined. The criteria selected include both benefit and cost aspects, such as rehabilitation area, carbon emissions, damage level, biodiversity, rehabilitation potential, and environmental impact. While Table 1 provides a clear overview of the criteria, the process of determining the weights for each criterion could be explained in more detail. It would be useful to clarify whether the weights were derived from expert consensus or another method. This explanation is important for understanding the validity and reliability of the weight assignment, which is crucial for ensuring the robustness of the study's results.

Determination of Alternative Data

Ten alternative locations were considered in this study, with criterion scores based on evaluations of each location as follows:

Table 2. Alternative Data

Alternative	C1	C2	C3	C4	C5	C6
South Tapanuli	Very Good	Poor	Fair	Good	Fair	Very Good
Mandailing Natal	Very Good	Fair	Poor	Very Good	Fair	Good
Langkat	Good	Bad	Poor	Very Good	Poor	Very Good
Simalungun	Fair	Fair	Poor	Fair	Fair	Fair
Karo	Fair	Fair	Bad	Fair	Bad	Fair
Toba	Fair	Bad	Bad	Good	Fair	Fair
Humbang Hasundutan	Poor	Fair	Poor	Fair	Bad	Good
Deli Serdang	Poor	Fair	Bad	Good	Fair	Fair
Dairi	Poor	Very Good	Very Good	Fair	Very Good	Poor
Pakpak Barat	Poor	Very Good	Very Good	Poor	Very Good	Poor

The study considers ten alternative locations for forest rehabilitation, with evaluation scores for each location based on the selected criteria. Table 2 presents the scores for each alternative. The evaluations were determined through field surveys, literature studies, and expert assessments, ensuring a transparent and credible methodology for the study's findings.

Quantitative Evaluation with the MOORA Method

We applied the MOORA method to examine six numerical factors that influence forest rehabilitation success. These factors include the rehabilitation area (a benefit), along with carbon emissions and ecosystem degradation (costs). Biodiversity and environmental impact are also treated as benefits, while rehabilitation potential is considered a cost. To ensure fair comparisons among the locations, we normalized the values so that all criteria were measured on the same scale. After normalization and calculating the total scores, we found that all the alternative locations received almost identical scores, with an average of 0.725.

Table 3. MOORA Normalized Scores for Ten Alternative Locations

Alternative	Area	Carbon Emissions	Ecosystem Degradation	Biodiversity	Rehabilitation Potential	Environmental Impact	Total Score
South Tapanuli	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Mandailing Natal	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Langkat	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Simalungun	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Karo	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Toba	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Humbang Hasundutan	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Deli Serdang	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Dairi	0.75	0.40	1.25	0.90	0.35	1.20	0.725
Pakpak Barat	0.75	0.40	1.25	0.90	0.35	1.20	0.725

These findings show that, when looking purely at the numbers, there isn't a significant difference between the locations. All of them appear to have a similar potential for rehabilitation based on the technical criteria we used. This suggests that we need to examine non-technical factors—such as social and cultural aspects—to better understand what might influence the overall success of the rehabilitation projects.

Qualitative Evaluation with the ORESTE Method

After analyzing the quantitative data, we applied the ORESTE method to assess the qualitative factors that influence the success of forest rehabilitation. In this step, we looked at elements such as local community participation, socio-cultural values, and institutional support. The ORESTE method uses something called Besson Projection to turn these qualitative assessments into numerical scores that can be compared across different locations.

Unlike the MOORA results, which were similar across all sites, the ORESTE findings revealed clear differences. South Tapanuli and Mandailing Natal scored the highest, showing that these areas have strong community support and favorable socio-cultural conditions for rehabilitation projects. In contrast, Pakpak Barat,

even though it has similar technical potential as the other locations, scored the lowest due to low community participation and various social challenges.

Table 4. ORESTE Scores and Ranking of Alternative Locations

Alternative	ORESTE Score	Rank
South Tapanuli	0.79125	1
Mandailing Natal	0.725	2
Langkat	0.585	3
Simalungun	0.5225	4
Karo	0.4025	5
Toba	0.4025	6
Humbang Hasundutan	0.4375	7
Deli Serdang	0.4875	8
Dairi	0.805	9
Pakpak Barat	0.675	10

These results show that social and cultural factors are very important for the success of forest rehabilitation. For instance, South Tapanuli and Mandailing Natal not only have strong technical potential but also enjoy robust community support, making them excellent choices for rehabilitation projects. On the other hand, although Pakpak Barat meets the technical requirements, it faces significant social challenges that could hinder the success of its rehabilitation efforts.

Integration of MOORA and ORESTE Results

Combining the results from the MOORA and ORESTE methods gives us a clearer picture of which rehabilitation sites should be prioritized. While the MOORA results indicate that all the locations have similar technical potential, the ORESTE analysis shows significant differences in social aspects. In plain terms, South Tapanuli and Mandailing Natal stand out as the top priority sites because they not only meet technical criteria but also enjoy strong community support, making them well-prepared for sustainable rehabilitation projects. On the other hand, even though Pakpak Barat has good technical potential, its considerable social challenges mean that it should not be considered a top priority.

Discussion of Findings

The results of this study align with those of Lapola et al. [1], who found that involving local communities is crucial for the success of environmental rehabilitation projects. Additionally, Khuc et al. [3] highlighted the importance of including socio-economic factors in forest rehabilitation decision-making. Therefore, combining the MOORA and ORESTE methods in our study shows that a multi-criteria, data-driven approach can yield results that are more fair, accurate, and sustainable.

4. CONCLUSION

This study combined the MOORA and ORESTE methods to evaluate and prioritize locations for forest and land rehabilitation in Indonesia by looking at both numerical data and qualitative factors. Our analysis shows that Mandailing Natal and South Tapanuli stand out as the best candidates for rehabilitation, as they achieved the highest overall scores. These areas offer a strong balance between ecological benefits—like high biodiversity and low environmental impact—and the challenges, such as carbon emissions and ecosystem degradation. This result supports previous research emphasizing the need to consider both ecological and social factors when planning effective rehabilitation strategies. Based on our findings, we recommend focusing rehabilitation efforts on high-potential areas like Mandailing Natal and South Tapanuli, while also keeping an eye on other promising locations. By using this multi-criteria approach, our study contributes to more informed, data-driven decisions for sustainable forest rehabilitation in the future.

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