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COMPARATIVE ANALYSIS OF MULTI-CRITERIA DECISION MAKING METHODS IN DETERMINING REDD+ PROJECT LOCATION

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ABSTRACT
The Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism is aimed at reducing global greenhouse gas (GHG) emissions. This study aims to develop a multi-criteria decision-making (MCDM) model specifically designed to prioritize locations for REDD + projects. The proposed research design focuses on developing a MCDM framework for determining the priority locations for projects using criteria such as climate impact reduction, contributions to local communities, and biodiversity conservation. The study utilized the Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), Weighted Product Method (WPM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to determine the prioritization of alternatives based on compromise solutions. The success of this research demonstrates that a systematic approach to determining priority locations can be effectively carried out using MCIM. This research is expected to aid policymakers and stakeholders in making more informed and effective decisions for environmental conservation and climate change mitigation.

INTRODUCTION

Global warming is one of the most significant challenges humanity faces today. It refers to the increase in Earth's surface temperature caused by excessive human activities (Al-Ghussain, 2019; Letcher, 2021; Mehmood et al., 2020; Purushotham Reddy et al., 2021; Zhou et al., 2022). Activities such as burning fossil fuels and deforestation elevate the concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) (Doll & Baranski, 2011; Duxbury & Mosier, 1993; Hema et al., 2019; Kabir et al., 2023; Raimi et al., 2021). These gases trap heat in the Earth's atmosphere, maintaining temperatures necessary for life. However, excessive human activities can lead to a rise in Earth's surface temperature, resulting in global warming (Celik, 2020; Klein & Anderegg, 2021; Shahzad, 2015; Shivanna, 2022). Its detrimental effects include extreme climate changes, increased frequency and intensity of natural disasters, and unpredictable seasonal patterns (Doll & Baranski, 2011).

In response, the Indonesian government, through the Ministry of Environment and Forestry (KLHK) (KLHK, 2021), reported a national greenhouse gas (GHG) emission of 1.228.721,13 Gg CO2e in 2022. The energy sector accounted for 59,19% of these emissions, followed by forestry and peatland fires at 18,02%, waste at 10,60%, agriculture at 7,38%, and industrial processes and product use (IPPU) at 4,82%.

Efforts to reduce GHG emissions in Indonesia have focused on sustainable natural resource and land management. Significant progress was marked in 2020 with a reduction in peatland fire emissions to 18 Gg Ton CO2e, a drastic decrease from 457 Gg Ton CO2e the previous year. This aligns with the reduced burnt peatland area, demonstrating the effectiveness of the policies and actions taken. Furthermore, Indonesia achieved a 47.45% GHG reduction from the Business as Usual (BAU) scenario in 2020, surpassing the Unconditional Nationally Determined Contribution (NDC) target of 29% for 2030. The forestry and land use (FOLU) sector played a crucial role, contributing significantly to national targets with an emission reduction of 581 Gg Ton CO_2e in 2020, or 75.99% of the NDC baseline. By targeting a Net Sink condition by 2030, where carbon absorption exceeds emissions, the government shows a strong commitment to not only meet NDC targets but also contribute to global GHG reduction efforts. FOLU is a strategic focal point, highlighting the importance of forest and peatland conservation and management as effective means to achieve these goals (KLHK, 2021). Integrating FOLU strategies into national and international agendas, including the Reducing Emission from Deforestation and Forest Degradation (REDD+) mechanism, reinforces the vital role of this sector in global emission reduction efforts.

REDD+ is a product of international discussions under the United Nations Framework Convention on Climate Change (UNFCCC) (Morita & Matsumoto, 2023). This mechanism allows developing countries to receive compensation for their participation in global climate change mitigation efforts by reducing deforestation and forest degradation. Additionally, REDD+ supports biodiversity conservation, sustainable forest management for socio-economic improvement, and enhancement of forest carbon stocks (Bhattarai et al., 2023). However, implementing this mechanism is challenging, often requiring the assistance of non-governmental organizations (NGOs) to help local communities manage their forests and participate in REDD+. NGOs play a crucial role in translating this mechanism to local communities to maximize the benefits of forest management. One such NGO assisting local communities in implementing REDD+ is the People Resources and Conservation Foundation (PRCF).

PRCF is a non-governmental, non-membership, non-profit organization established in the United States under Section 501(c) (Doll & Baranski, 2011) of the US Internal Revenue Code. PRCF Indonesia was established in October 2000 and remains active in assisting communities with forest management, including implementing REDD+. PRCF Indonesia uses the Climate, Community, & Biodiversity Standards (CCBS) from Verra, which supports activities addressing climate change, promoting local community development, and conserving biodiversity. These standards require projects to conduct comprehensive assessments of their impacts on the climate, local communities, and biodiversity. Due to the numerous assessment factors, PRCF Indonesia faces challenges in prioritizing locations for REDD+ projects. Therefore, a careful approach is needed to determine priority locations for better REDD+ project implementation.

Based on research references on assessing the effectiveness of REDD+ implementation and forest sustainability in South Asian countries such as Nepal, Sri Lanka, India, Bangladesh, and Pakistan, using Multi-Criteria Decision Making (MCDM) methods with three sustainability evaluation indicators: socio-economic, policy and governance, and environmental (Tahir et al., 2024).

This study aims to determine the priority locations for REDD+ projects using a multi-criteria decision-making (MCDM) model with criteria such as ecosystem restoration, reforestation, carbon emission reduction, educational improvement, and species conservation. The research contribution of the study lies in the development and application of a multi-criteria decision-making (MCDM) model specifically designed to prioritize locations for REDD+ (Reducing Emissions from Deforestation and Forest Degradation) projects. By incorporating a diverse set of criteria—such as ecosystem restoration, reforestation, carbon emission reduction, educational improvement, and species conservation—the study provides a comprehensive approach to decision-making in the context of REDD+ initiatives. This contribution is significant as it offers a systematic method to identify and prioritize areas where REDD+ projects could have the most impact, potentially aiding policymakers and stakeholders in making more informed and effective decisions for environmental conservation and climate change mitigation.

METHODS

This research employed the Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW) to evaluate REDD+ implementation. AHP helps determine the importance of each of the three factors in the success of REDD+ implementation, while SAW calculates the overall score based on the importance of these factors.

This study began with a literature review and data collection from the research subject, PRCF Indonesia. The aim is to ensure that the implementation of the MCDM methods yields optimal results. The proposed research design focuses on developing a MCDM framework for evaluating potential REDD+ project sites. This framework will consider three primary criteria: impact on climate, contribution to local communities, and biodiversity conservation, based on the CCBS. Each primary criterion will be broken down into several relevant sub-criteria to facilitate a comprehensive assessment of potential project locations.

The first step involves using the AHP to determine the weights of importance for each criterion and sub-criteria. Experts, including the Director of PRCF Indonesia, will complete a detailed questionnaire involving pairwise comparisons to assess the relative importance of each criterion and sub-criteria. The resulting weights will be used to prioritize the criteria and sub-criteria for the REDD+ project site evaluation. Following the determination of weights, SAW method will be employed to calculate the overall score for each potential project location. Scores assigned to each location for each sub-criterion will be multiplied by the corresponding weights obtained from AHP, and the weighted scores will be summed to obtain an overall score for each location.

To further evaluate each alternative, WPM will be used. This involves assigning scores to each location for each sub-criterion and multiplying each score by its corresponding weight from AHP. The product of these weighted scores will help rank the locations based on their overall performance. Additionally, TOPSIS will assess the proximity of each alternative to the ideal solution. The ideal and negative-ideal solutions will be identified based on the scores of all locations, and the Euclidean distance of each location from these solutions will be calculated. The relative closeness of each location to the ideal solution will then be computed.

Finally, VIKOR method will determine the prioritization of alternatives based on compromise solutions. This involves calculating the utility and regret measures for each location, and the VIKOR index will combine these measures to identify a compromise solution.

Based on the results from SAW, WPM, TOPSIS, and VIKOR, the priority locations for the REDD+ projects will be determined. Locations with the highest overall scores and rankings across these methods will be prioritized for project implementation. The expected outcome is a comprehensive and robust evaluation framework for assessing potential REDD+ project sites, leading to the identification of high-priority locations that align with the objectives of climate impact reduction, community contribution, and biodiversity conservation. This framework is anticipated to enhance decision-making processes for the implementation of REDD+ projects, ensuring that resources are allocated to the most beneficial and sustainable locations.

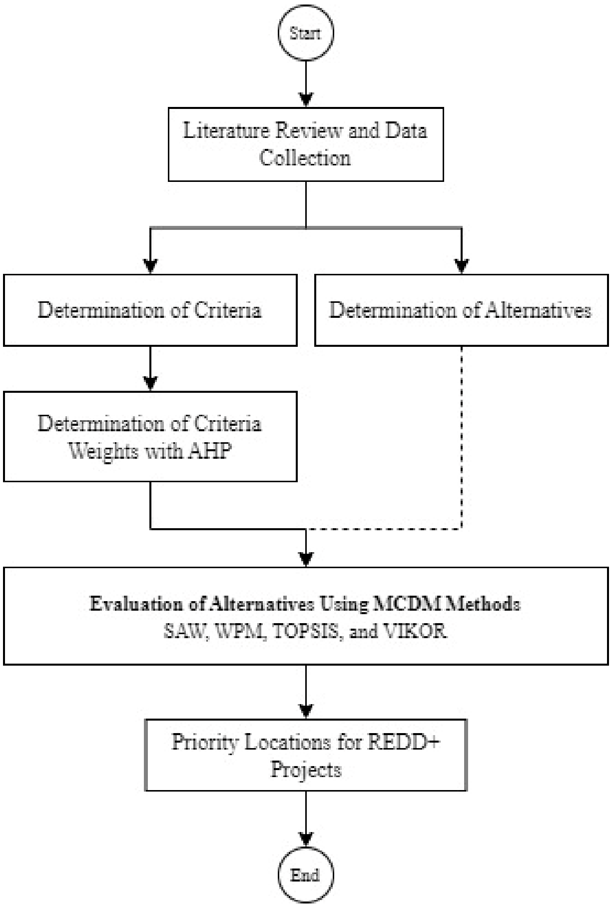

Figure 1. Development Model Design for Priority REDD+ Locations.

Data collection was conducted through a literature study by reading and understanding the document "Rimba Pakai Kemuka Air – Forest for Future," which refers to CCBS. This literature study resulted in several criteria used for evaluating the priority locations for the REDD+ project. The study also identified five village forests as potential locations to be used as alternatives in the MCDM method implementation. The results of the literature study are shown below.

Table 1. Criteria

Label	***Criteria***
C1	Forest Ecosystem Restoration
C2	Active Reforestation and Natural Regeneration
C3	Increased Children's Educational Opportunities
C4	Carbon Emission Reduction
C5	Forest Loss Reduction
C6	Skill and Knowledge Enhancement
C7	Women's Skill and Knowledge Enhancement
C8	Job Creation
C9	Women's Job Creation
C10	Livelihood Improvement
C11	Women's Livelihood Improvement
C12	Improved Access or Quality of Education
C13	Conservation of Threatened and Endangered Species

Table 2. Alternatives

Label	***Village Forest***
HDBB	Bukit Belang
HDNP	Nyuai Peningun

HDBT	Batang Tau
HDPB	Punjung Batara
HDBL	Bumi Lestari

After determining the criteria and alternatives for the MCDM method implementation, data collection also resulted in the values of each criterion for each alternative. This data was processed into an initiation matrix to be used with the MCDM method. The initiation matrix results can be seen in Table 3.

Table 3. Initiation Matrix

Criteria	*HDBB*	*HDNP*	*HDBT*	*HDPB*	*HDBL*
C1	66.096	109.107	8.775	52.326	33.696
C2	28,417	46,928	3,775	22,502	14,498
C3	51	44	40	59	46
C4	9,144	43,845	244	19,276	4,264
C5	392	412	282	351	341
C6	430	452	308	386	374
C7	188	179	128	156	161
C8	14	15	10	13	12
C9	5	3	5	3	4
C10	100	90	72	106	87
C11	27	32	26	30	23
C12	51	44	40	59	46
C13	9	10	7	8	8

Based on Table IV.3, the first column lists the criteria (C1 to C13) evaluated for each village forest alternative (HDBB, HDNP, HDBT, HDPB, and HDBL). The values in these columns represent the scores for each criterion at each alternative location.

In addition to the initiation matrix, determining the priority location for the REDD+ project using MCDM also requires the weight values for each criterion. These weight values are obtained using the pairwise comparison matrix in the AHP method. In AHP, each criterion is compared in pairs to determine its importance relative to others. The comparison results are entered into a pairwise comparison matrix, using Saaty's scale from 1 to 9, as shown in Table 4.

Table 4. Saaty Comparison Scale

Scale	*Description*
1	Both criteria are equally important
3	One criterion is slightly more important than the other
5	One criterion is more important than the other
7	One criterion is significantly more important than the other
9	One criterion is absolutely more important than the other
2, 4, 6, 8	Intermediate values between adjacent preferences

The pairwise comparison matrix is then created by the Director of PRCF Indonesia, who assigns the comparison scale values to each criterion based on a questionnaire. And the next step is to normalize the pairwise comparison matrix. Normalization is done by dividing each criterion by the total for each respective criterion. The final step in determining the priority weights for each criterion is to calculate the average value of the values in each row. The resulting weight values are shown in Table 5.

Table 5. Criterion Weights

Criteria	*Weight*
C1	0.217
C2	0.141
C3	0.122

C4	0.103
C5	0.121
C6	0.064
C7	0.056
C8	0.047
C9	0.040
C10	0.029
C11	0.025
C12	0.024
C13	0.011
Total	1.000

Once the weight values for each criterion are obtained, these weights will be used in other MCDM methods, such as SAW, WPM, TOPSIS, and VIKOR.

RESULTS

Comparision

The results of data processing using the four MCDM methods in determining the priority locations for the REDD+ project can be seen in Table IV.6.

Table 6. Comparison of Priority Rankings for REDD+ Project Locations

Rank	*SAW*	*WPM*	*TOPSIS*	*VIKOR*
1	HDNP	HDNP	HDNP	HDNP
2	HDBB	HDBB	HDBB	HDBB
3	HDPB	HDPB	HDPB	HDPB
4	HDBL	HDBL	HDBL	HDBL
5	HDBT	HDBT	HDBT	HDBT

From the table above, the results of data processing using the four MCDM methods yield the same rankings for each alternative. This indicates the consistency and reliability of the methods used, providing assurance that various approaches yield uniform evaluations of the existing alternatives. However, this similarity in results also suggests a potential lack of sensitivity in differentiating the performance of alternatives based on the established criteria.

This consistency validates that the data and analysis conducted are quite stable but also indicates the need for further review of the criteria weights used and possibly the addition of more specific criteria to enhance differentiation between alternatives. By adjusting and adding more relevant criteria, the evaluation results can become more detailed and accurate, providing deeper insights into the decision-making process.

Similarly Analysis

To gain a deeper understanding of the similarity or resemblance of ranking results among the four MCDM methods, a similarity analysis was conducted using the Pearson correlation method. This analysis was performed using the Python programming language with the help of Google Colab software, with the ranking values from the four methods as input. The results of this similarity analysis can be seen in Figure 2.

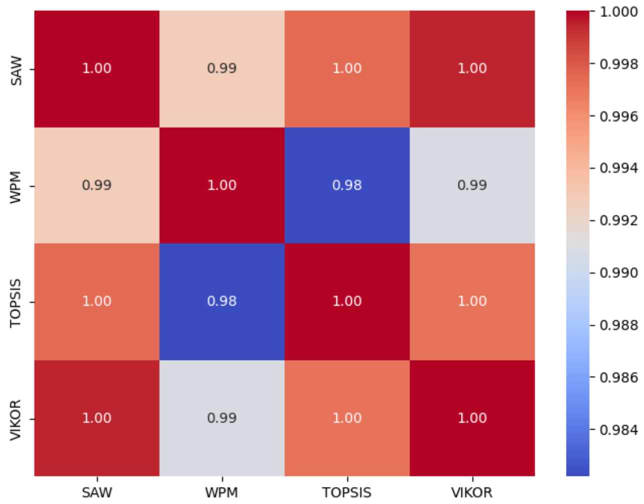

Figure 2. Pearson Correlation Values for Each Pair of Methods

From the figure above, the similarity analysis using the Pearson correlation method between the SAW, WPM, TOPSIS, and VIKOR methods shows that these four methods provide very similar preference values for the analyzed alternatives. The very high correlation values between all these methods indicate that the methodological differences do not significantly affect the evaluation of the alternatives. This uniform correlation suggests that all methods handle the criteria and weights in a similar manner, resulting in consistent evaluations among them. This result confirms that the four methods can be reliably used to provide cohesive results in this preference analysis.

CONCLUSION

The study uses four MCDM methods to evaluate the success of REDD+ projects in countries. The results show consistency and reliability, indicating uniform evaluations of alternatives. Socio-economic factors were found to be the most influential in the success of REDD+ programs. Nepal scored highest, indicating its program's effectiveness, while Pakistan scored lowest. The study demonstrates that a systematic approach using MCDM can be effective in determining priority locations for REDD+ projects. Key criteria such as climate impact, local community contributions, and biodiversity conservation will be integrated with other methods, providing a broader evaluation perspective and enabling more accurate and comprehensive identification of optimal priority locations. This approach demonstrates the effectiveness of MCDM in determining priority locations for REDD+ projects.

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