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# Multidimensional Analysis of Sustainability and Integration of Sustainable Energy Practices in Petroleum Field Management

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**ABSTRACT**

This study illustrates the importance of sustainable energy management in the context of oil field management in Indonesia. Using the Rappetro approach, this research evaluates the sustainability of oil field management across various dimensions, including ecological, economic, socio-cultural, technological, and legal-institutional aspects. Findings indicate that the sustainability index for all dimensions—ecology (64.07%), economy (57.72%), socio-cultural (52.91%), technology (64.44%), and legal-institutional (61.7%)—is robust. This signifies that oil exploration and exploitation operations in the area have effectively integrated conservation principles. Energy management and balanced integration of ecological, economic, and technological aspects in oil field management play a key role in ensuring long-term sustainability. Theoretically, this research provides valuable insights for the energy sector by highlighting the sustainability of oil field management. Its implications are relevant in shaping sustainable energy practices, emphasizing the need for a comprehensive approach in every stage of oil resource exploration and exploitation. Thus, this study makes a significant contribution to guiding policies and practices that support sustainable energy development in the future.

**Keywords:** Energy Management, Sustainable Energy Practices, Energy Sector, Environment, Multi-Dimensional Analysis, Oil Field
**JEL Classifications:** L2, L23, L5, L52, L53

## 1. INTRODUCTION

Indonesia, as the largest producer of crude oil in Southeast Asia, relies heavily on Riau Province as its largest oil-producing region in the country (PDTIESDM, 2016; BP, 2022). One of the major oil fields in Riau Province is the Zamrud Field, discovered in 1975 and started production in 1982 (Setiani, 2004). This field was managed by PT CPI from 1979 to 2002, before being transferred to the joint operating body (BOB) under a production sharing contract (KPS) for 20 years (2002-2020), signed on August 8, 2002. Since August 2022 until August 2042, the management of this field is fully under PT Bumi Siak Pusako, a company owned by Siak Regency. Despite being an aging field, its contribution to oil and gas production in Indonesia remains significant. In 2019, the Zamrud oil field produced approximately 4,000 barrels of oil per day, with 194 active wells out of a total of 450 wells (Bumi Siak Pusako, 2019).

Covering an area of 374 hectares, this field is located within the conservation area of Zamrud National Park, which spans 31,480 hectares (Asriwandari et al., 2021). Most of the field area consists of peat soil and includes two natural lakes. The majority of the oil reserves in this field are located beneath these two lakes at a depth of around 3,000 feet (1,000 m). The initiative to establish the conservation area was initiated by PT Caltex Pacific Indonesia and supported by the Indonesian government, officially designating this oil field as a Wildlife Sanctuary through Ministerial Decree No. 812/MenPPLH/8/79. On May 4, 2016, the Minister of Environment and Forestry of the Republic of Indonesia changed the function of the Wildlife Sanctuary of Danau Pulau Besar/Danau Bawah and the Tasik Besar Serkap Permanent Production Forest Area into Zamrud National Park in Siak Regency, Riau Province, covering approximately 31,480 hectares (Rahmadani and Mashur, 2020).

Although oil field development brings significant benefits, it also entails various negative impacts. The impacts of oil field development include potential soil contamination, changes in the quality, quantity, and availability of surface water and groundwater, water and soil salinization, acid drainage, heavy metal contamination, erosion, subsidence, soil instability, changes in water flow, significant changes in land use, habitat loss, loss of biodiversity of rare or endangered flora and fauna, spread of plant diseases, and the impacts of toxic or hazardous substances (Enyoghasim et al., 2019; Paramita, 2022; Faoziyah, 2023). Additionally, these activities can trigger social issues and unrest within communities (Orazalin and Mahmood, 2018). Therefore, the management of oil and gas fields, which have a limited lifespan, must be carried out as effectively as possible to maximize positive impacts and minimize negative impacts for sustainable development (George et al., 2016).

Exploration and exploitation activities of oil and gas must be optimally managed to ensure that the conservation function of peatland areas is not disrupted. From a cross-sectoral perspective, oil and gas exploitation in national park areas raises controversy. On one hand, the forestry sector is concerned that these activities will reduce the conservation function of the area (Ahmad et al., 2021; Joel and Oguanobi, 2024). On the other hand, the oil and gas sector view these activities as an important source of revenue needed to meet national energy needs. This imbalance can harm both sectors if the conservation function is compromised and oil reserves are not optimally exploited. Conservation generally prohibits the exploitation of natural resources in a particular area, but oil operations are often exempted because they were established before the designation of the area as a conservation zone (Dudin et al., 2019; Cherepovitsyn et al., 2021).

Given this complexity, research on energy management becomes crucial for the development of more sustainable energy policies. This approach illustrates the efforts of sustainable energy management by balancing oil production and environmental conservation. Oil production must be carried out effectively, integrating various management aspects that consider environmental sustainability (Chandranegara and Hoesei, 2019; Hossein Motlagh et al., 2020). An integrative approach to energy management provides an important example for developing more sustainable energy policies. Sustainable energy management not only focuses on production efficiency and economic profits but also on environmental protection, social welfare, and biodiversity conservation. Sustainable energy practices encompass various strategies, such as the application of environmentally friendly technologies, continuous monitoring of environmental impacts, and the involvement of local communities in decision-making processes (Gardas et al., 2019; Al-Hussein et al., 2022). Moreover, policies that support sustainable energy management must include strict regulations on exploration and production practices, as well as incentives for companies that invest in green technologies and environmentally friendly practices.

## 2. RESEARCH METHODS

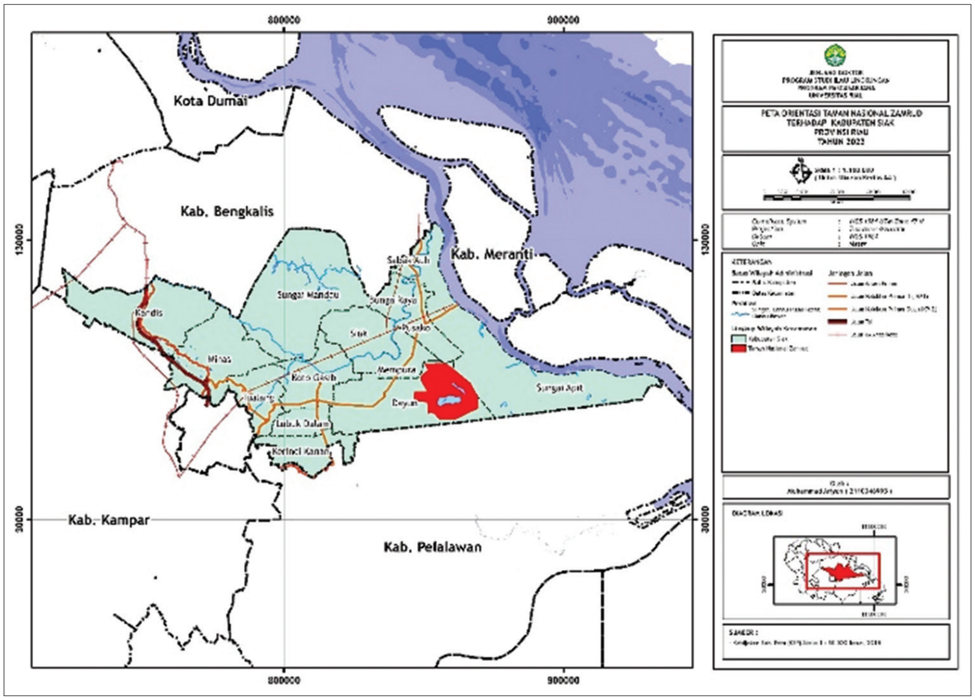
This research was conducted at the Zamrud oil field in Dayun Village, Dayun District, Siak Sri Indrapura Regency, Riau Province, Indonesia. Figure 1 shows that geographically, the study location is situated at coordinates 00°35”-00°45” N and 102°10”-102°29” E. The types of data used in this research include primary and secondary data. Primary data were obtained directly through field observations, interviews, and questionnaires with informants/respondents from the Natural Resources Conservation Agency of Riau Province, the Riau Provincial Government, the Siak Regency Government, SKK Migas (Special Task Force for Upstream Oil and Gas Business Activities), leaders and employees of the oil and gas company PT Bumi Siak Pusako (contractor), community leaders, academics, and residents around the national park (residents in Dayun Village, Sungai Rawa Village, and Rawa Mekar Sari Village).

The principles of appropriateness and sufficiency guided the selection of sources/respondents. The principle of appropriateness selected respondents based on their skills/knowledge and relevance to the research issue, while the principle of sufficiency did not require a specific number of respondents but focused on the completeness of the data obtained (Putra et al., 2023). Data collection scores were filled based on a good or bad scoring scale and were reinforced with secondary data to build the quality of oil field management. Secondary data in this research included related literature, research journals, reference books, and data from the Central Statistics Agency, the Ministry of Energy and Mineral Resources, or other government agencies, as well as data from PT Bumi Siak Pusako in the form of environmental management implementation reports such as harmonization studies, environmental impact analyses, environmental management plans, and environmental monitoring plans.

This research focuses on five dimensions of sustainable oil management in the National Park of Siak Regency: Ecology, economy, social, technology, and legal institutional. Each dimension consists of variables grouped based on criteria on an ordinal scale, known as multidimensional scaling (MDS) or more precisely a multivariate coordination approach. The MDS approach is used for sustainability analysis, utilizing the Rapfish software updated to Rap-Petro (Rapid Appraisal for Petroleum Ecosystem). MDS is a multivariate statistical method that uses several parameters to determine the position of objects based on similarities and differences (Pitcher, 2004). The MDS approach, leveraging multidimensionality and multiple indicators within variables, is well-suited for studying the sustainability conditions of oil field management in this national park. MDS analysis is used to ensure the dependence or relationship between variable data (Surjono et al., 2021). MDS encompasses various types of algorithms, allowing data to be grouped into multiple categories (Jaworska and Chupetlovska-Anastasova, 2009).

In the context of energy management and sustainable energy practices, MDS is used to rank a set of attributes relevant to sustainability, followed by scaling and rotating the data. RAPFISH, which can be applied in various scientific fields such as ecology, economics, ethics, and social sciences, facilitates a comprehensive analysis of

**Figure 1:** Map of the research site in the Zamrud field

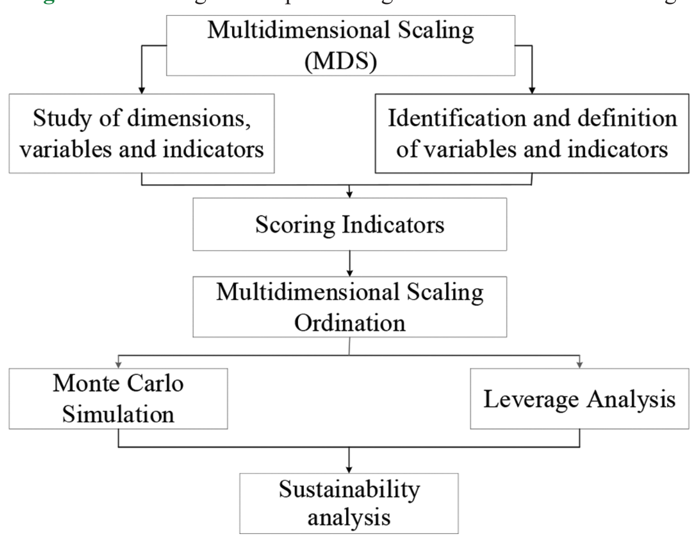



sustainability (Chaliluddin et al., 2023). Errors in the analysis can be minimized using Monte Carlo simulation, while the influence of each characteristic on the sustainability score can be estimated using a stepwise process (Azizah et al., 2023). The results of the sustainability analysis are expressed on a scale of 0% to 100%, and scores from various categories can be combined into a kite diagram for clearer visualization (Ramadani et al., 2019; Santoso et al., 2023).

This approach reflects sustainable energy management, where oil production is balanced with environmental conservation efforts. By integrating ecological, economic, social, technological, and legal institutional dimensions, the MDS method provides a holistic and systematic guide for evaluating the sustainability of oil field management (Igbinenikaro et al., 2024). This approach emphasizes the importance of considering various interrelated factors in natural resource management, ensuring that energy practices are not only economically beneficial but also environmentally friendly and socially sustainable. The implementation of MDS in this research provides a model that can be adopted by other energy sectors to achieve a balance between resource exploitation and environmental preservation (Ahmad et al., 2021; Al-Shetwi, 2022). Figure 2 shows the stages of MDS analysis.

The stages used to analyze the sustainability status of oil field management involve several steps. First, data analysis for the sustainability of oil field management in the national park, Siak Regency, is conducted based on field surveys and literature research. Second, the quality and scores for each ecological, economic, social, technological, and legal institutional dimension are determined using the Rapfish literature. This step is followed by assessing each attribute through observation, interviews, and literature studies. Next, multidimensional scaling (MDS) analysis is performed to establish ordination and stress values using the MS Excel-based Rapfish software. The final stage involves quality rotation to

**Figure 2:** The Stages of Implementing the multidimensional scaling




identify the position in the ordination from poor to good, followed by leverage analysis to identify attribute sensitivity and Monte Carlo analysis to account for uncertainty aspects (Salsabila, 2021; Hanifah et al., 2023). Based on the sustainability status index values for each dimension of oil field management in the national park, Siak Regency, the results can be categorized as presented in Table 1.

## 3. RESULTS

Sustainable energy management includes steps such as continuous monitoring of environmental quality, the use of environmentally friendly technology, and the implementation of comprehensive environmental management plans (Kamran et al., 2020). Additionally, collaboration with conservation agencies and other stakeholders ensures that all oil exploration and production activities are carried out with consideration for ecological impacts (Strielkowski et al., 2021). In the investigation of ecological sustainability, nine attributes have been identified as determining factors: air quality, river/lake water quality, canal water quality, forest area, vegetation diversity, tree species density, protected animals, erosion and sedimentation, and plankton diversity. Evaluation of these attributes within the ecological dimension was conducted based on observational data, interviews with experts, and a review of harmonization studies carried out by PT. BSP Pertamina Hulu in collaboration with the Riau Province Natural Resources Conservation Agency (BBKSDA). Additionally, the analysis included environmental impact assessments, environmental management plans, and environmental monitoring reports from the oil company. Figure 3 shows that the application of multidimensional scaling (MDS) analysis using the RAPPETRO Program resulted in an index of 64.07, categorizing it as moderately sustainable in the ecological dimension. This indicates that the management of oil resources in Zamrud National Park, Dayun Subdistrict, Siak Regency, is being carried out effectively from an ecological perspective.

In Figure 3, the examination shows that the presence of the oil and gas industry in Zamrud National Park does not have a significant negative impact on the flora and fauna habitat. The oil and gas companies demonstrate a strong commitment to conserving the protected area, evidenced by the increased coverage of peat swamp forests. Paiman et al. (2018) and Fadillah and Soesanto (2023) emphasize the importance of forests as a vital ecological foundation, a resource, and a support for economic growth, as well as for improving well-being and health. This underscores the urgent need for global forest conservation and regeneration (Shynybekov et al., 2023). Leverage analysis was conducted to identify sensitive attributes affecting the sustainability index in the ecological dimension. A combination of leverage analysis and Pareto analysis revealed that the sustainability of oil field management is primarily influenced by five sensitive attributes: tree species density, forest area, protected animals, vegetation diversity, and canal water quality. The cumulative sensitivity associated with these factors is 76.95%.

**Table 1: Sustainability assessment status category based on MDS index value**

| Index value | Criteria assessment |
|---|---|
| 0-25 | Poorly sustainable |
| 25-50 | Less sustainable |
| 50-75 | Moderately sustainable |
| 75-100 | Highly sustainable |

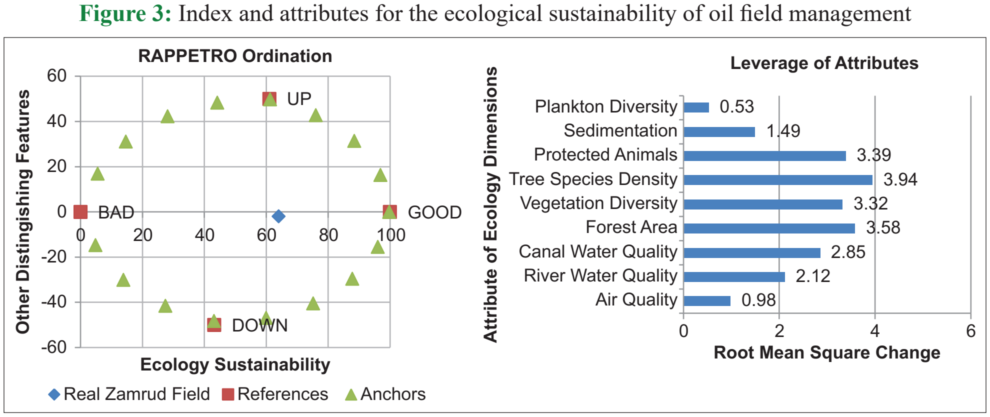
MDS: Multidimensional scaling

The production of oil balanced with environmental conservation efforts reflects sustainable energy management practices. Sustainable energy management not only focuses on production efficiency and economic benefits but also on the protection and preservation of ecosystems (Kabeyi and Olanrewaju, 2022). By integrating various ecological aspects into energy management, this practice ensures that oil exploration and production do not harm the environment and support long-term sustainability (Amran et al., 2020). With leverage analysis results showing key attributes affecting ecological sustainability, the management of the Zamrud oil field can serve as a model for sustainable energy practices. This approach emphasizes the importance of integrating ecological dimensions into energy management, demonstrating that oil production can be conducted responsibly and sustainably without compromising environmental conservation.

In the evaluation of the economic sustainability dimension, the government's main economic strategy focuses on the oil and gas sector, recognized as key to national sustainable development (Beisembekova et al., 2022). The analysis of the sustainability status of oil field management in the economic dimension includes 12 attributes: the contribution of oil and gas to Siak's GRDP, the income of the surrounding community, job opportunities, business opportunities, the level of domestic component, investment feasibility, road infrastructure development by oil and gas companies, monthly employee income, share ownership, community economic development partnership programs, ASR costs, and the contribution of oil and gas to Siak's regional budget. The assessment of these attributes involves economic calculations for the oil field using PSC and gross split contracts, as well as interviews and questionnaires administered to oil company employees and villages around the oil field.

Based on the MDS analysis using the RAPPETRO program in Figure 4, the sustainability status of oil field management in the economic dimension is determined to be 57.72. This indicates that the economic management of the oil field is sufficiently sustainable, suggesting that the oil and gas industry activities in the field are economically viable and contribute significantly

**Figure 3:** Index and attributes for the ecological sustainability of oil field management



to regional economic improvement. The focus on sustainable development is considered essential for the effective functioning of any economic entity, whether at the national, regional, industry, or organizational level (Chernyaev and Rodionova, 2017). Fahriza and Hartono (2018) argue that regions dependent on oil and gas commodities, as evidenced by their contribution to GRDP, experience faster expansion compared to regions that do not produce oil and gas. Oil and gas resources have proven beneficial to regions, accelerating industrial development beyond oil and gas faster than in other areas. Riau Province has been the largest recipient of profit sharing in Indonesia, with Siak District ranking fourth in receiving these funds nationwide. From 2012 to 2021, oil and gas have substantially contributed to Siak's GRDP, averaging 32.79%. Key economic indicators such as domestic component, community income, job opportunities, and business opportunities all show favorable conditions. According to the Central Statistics Agency (Badan Pusat Statistik), the oil and gas sector has consistently been the major contributor to Siak District's GRDP from 1978 to 2022.

Furthermore, leverage analysis was conducted to identify sensitive attributes influencing the sustainability index in the economic dimension. Seven sensitive economic attributes shape the sustainability of oil field management, including economic feasibility, share ownership, infrastructure development, domestic component level, business opportunities, oil and gas DBH contribution, and employee income. The cumulative sensitivity associated with these factors is 79.28%. This outcome demonstrates how sustainable energy management can be achieved by ensuring that oil and gas operations provide significant economic benefits while maintaining balance with other aspects of sustainability. By integrating the economic dimension into sustainable energy management, the management of oil fields in Siak District can provide significant long-term benefits to the local and national economy while still preserving balance with environmental and social sustainability.

In Figure 5, the analysis results indicate substantial community support for oil and gas exploration and exploitation activities, commendable competence in the company's workforce, low incidence of work accidents, and noteworthy efforts by the company to improve health, education, and public facilities through CSR programs. To truly fulfill its social function, these positive aspects must be maintained and enhanced, especially in terms of increasing employment and business opportunities for local communities and maximizing the benefits of CSR programs in health, education, infrastructure, and local wisdom. Maintaining and improving these social aspects is key to sustainable energy management (Gardas et al., 2019). Such efforts not only support the well-being of local communities but also ensure the sustainability of oil and gas industry operations by gaining support from local stakeholders. Moreover, this approach helps create a stable and conducive environment for long-term operations (Ahmad et al., 2021; Strielkowski et al., 2021).

Leverage analysis was conducted to identify sensitive attributes influencing the sustainability index in the social dimension. A combination of leverage analysis and Pareto analysis was used to identify sensitive attributes influencing the sustainability of oil field management. As illustrated in Figure 5, five sensitive

**Figure 4:** Index and attributes for economic sustainability of oil field management

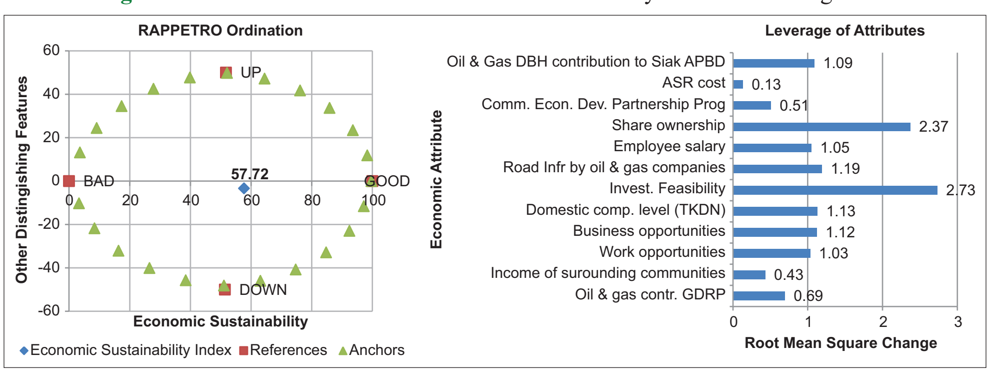
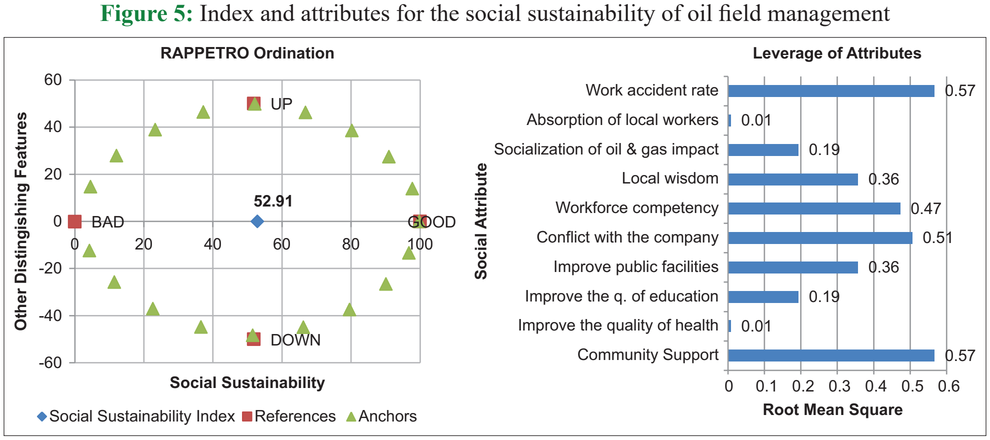



**Figure 5:** Index and attributes for the social sustainability of oil field management



attributes in the social dimension affecting the sustainability of oil field management include accident rates, community support, conflicts, workforce competence, and public facilities improvement. The cumulative sensitivity associated with these factors is 76.51%. These attributes were considered in determining the next steps in developing a sustainability model for oil field management. Meanwhile, the following attributes contribute a value of 23.49%, addressing issues related to sensitive attributes such as local wisdom, environmental impact awareness, education quality improvement, local employment absorption, and health improvement. By integrating these social aspects into sustainable energy management, companies can ensure that oil and gas operations not only generate economic profits but also deliver significant social benefits. This is part of a broader strategy of sustainable energy management that balances economic, social, and environmental interests (Dudin et al., 2019).

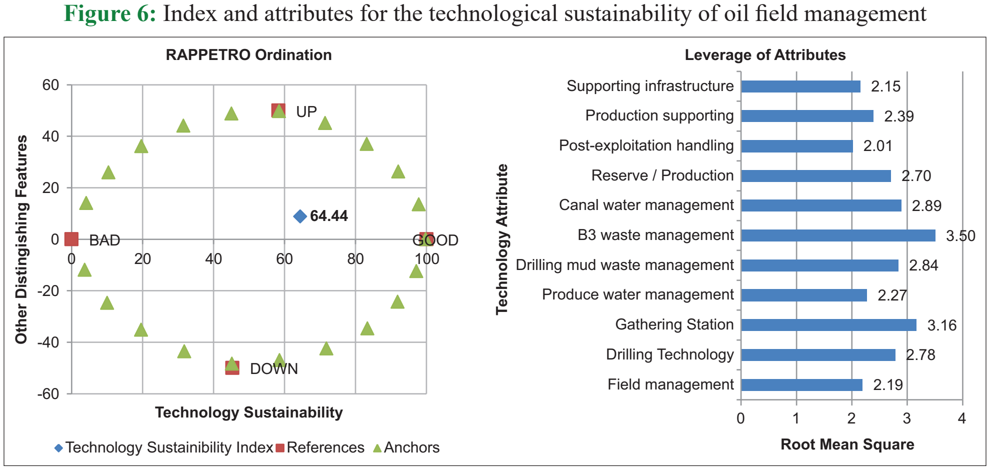
To assess the sustainability of the technological dimension in oil field management, an analysis was conducted covering 10 key attributes, including stakeholder partnership coordination, implementation of monitoring and supervision, zoning regulations, transparency, accountability, effectiveness and efficiency, participation, independence, fairness, and specific government regulations. Assessment of these attributes was obtained through observations, interviews, and questionnaires provided to oil company employees and the community. Attributes in the technological dimension ranged from moderate to good. Based on the results of multidimensional scaling (MDS) analysis using the RAPPETRO program in Figure 6, the sustainability status of oil field technology management was determined to be 64.44. This implies that the administration of oil field technology is sufficiently sustainable, indicating the use of modern technology while maintaining environmental sustainability.

The sustainability of technology in oil and gas operations demonstrates that companies have adopted practices and technologies that not only enhance production efficiency but also minimize environmental impact (Kabeyi and Olanrewaju, 2022). Modern technologies, such as real-time monitoring, integrated data management systems, and waste processing technologies, play a crucial role in achieving these goals. By maintaining and continuously improving these attributes, companies can ensure that oil and gas operations are not only economical but also sustainable from environmental and social perspectives (Kamran et al., 2020). The integration of advanced technology and best practices in sustainable energy management demonstrates a company's commitment to positively contribute to sustainable development and maintain a balance between energy needs and environmental conservation. Thus, these results highlight the importance of technology in sustainable energy management, where the use of modern technology can help reduce the environmental impact of oil production, improve energy efficiency, and ensure the long-term sustainability of oil and gas operations (Gyamfi et al., 2021).

In Figure 6, it can be seen that the management of oil exploration and exploitation activities in the field follows the guidelines outlined in the proof of delivery document, utilizes directional drilling techniques, and ensures proper processing and utilization of produced water as injection water. Toxic waste is treated appropriately in accordance with legal regulations and policies. Additionally, these activities fully implement Site Recovery and Restoration programs, maintain well-functioning production equipment, and boast satisfactory supporting infrastructure. In the technological dimension, leverage analysis identifies eight sensitive attributes that influence sustainability indices: management of toxic waste, collection stations, canal water management, sludge waste management, drilling technology, reserves/production, production equipment, and management of produced water. The cumulative sensitivity associated with these factors is 78.01%. These attributes are considered in determining the next steps in developing a sustainability model for oil field management. Meanwhile, the following attributes contribute a value of 21.99%, addressing issues related to sensitive attributes such as field management, infrastructure, and post-mining.

The sustainability analysis of oil field management in the legal and institutional dimension encompasses 10 attributes: Coordination of partnerships among stakeholders in the national park, implementation of monitoring and supervision, zoning regulations, transparency, accountability, effectiveness and efficiency, participation, independence, fairness, and government regulations governing the existence of the park. Assessment of these attributes was obtained through interviews and questionnaires given to oil company employees and the community. Attributes in the legal and institutional dimension range from poor to good. Based on the Multidimensional Scaling (MDS) analysis using the RAPPETRO

**Figure 6:** Index and attributes for the technological sustainability of oil field management



program, as shown in Figure 6, the sustainability status of oil field management in the legal and institutional dimension is 61.70. This indicates that the management of the oil field from a legal and institutional perspective is sufficiently sustainable, indicating that the company's governance is strong and adheres to principles of Good Corporate Governance. The results of the legal and institutional dimension analysis show that coordination among stakeholders is well-executed, monitoring and supervision are conducted regularly, and corporate governance for transparency, accountability, effectiveness, efficiency, responsibility, and independence indicators is fairly good. The existing legal institutional framework demonstrates that corporate governance is robust and compliant with principles of Good Corporate Governance. The integration of these various dimensions demonstrates that the management of oil fields focuses not only on economic aspects but also on environmental, social, technological, and legal and institutional aspects. By considering the dimensions of economy, ecology, social aspects, technology, and legal and institutional frameworks, the management of oil fields shows a holistic approach necessary to achieve sustainability in energy management (Hossein Motlagh et al., 2020).

In Figure 7, the results of the Root Mean Square (RMS) percentage values are organized based on sensitive attributes in the legal and institutional dimension and obtained through Pareto analysis. These findings reveal that five sensitive institutional legal dimensions such as independence, justice, zoning, stakeholder coordination, and monitoring and supervision implementation play crucial roles in determining the sustainability of oil field management. The cumulative sensitivity associated with these attributes is 79.60%. These attributes are considered in determining the next steps in developing a sustainability model for oil field management. Meanwhile, the following attributes contribute 20.40%, addressing issues related to sensitive attributes such as transparency, accountability, effectiveness and efficiency, participation, and national park law and government policies. Monte Carlo analysis is used for validity assessment to measure the impact of errors in MDS. Findings from the Monte Carlo analysis reveal a confidence level of 95%. Minor differences (with relatively small discrepancies) in each dimension indicate that the use of MDS in simulation is marked by high confidence levels. The difference in sustainability index between MDS and Monte Carlo in the context of Oil Field Management is illustrated in Table 2.

**Table 2: Monte Carlo analysis of differences in sustainability indices in oil field management**

| No | Dimension | Nilai MDS (%) | Monte Carlo (%) | Difference (%) |
|---|---|---|---|---|
| 1. | Ecology | 64.07 | 63.39 | 0.68 |
| 2. | Economic | 57.72 | 57.66 | 0.06 |
| 3. | Social | 52.91 | 52.69 | 0.22 |
| 4. | Technology | 64.44 | 63.37 | 1.07 |
| 5. | Institutional law | 61.70 | 61.55 | 0.15 |

MDS: Multidimensional scaling

The marginal or relatively small differences observed between the sustainability indices from MDS and Monte Carlo are below 5%. Therefore, it is concluded that the sustainability index values in oil field management are considered valid and indicate minimal random errors. These small differences suggest that inherent errors in the analytical process can be reduced or eliminated. Factors contributing to this include scoring each attribute, multidimensional assessment variations due to relatively minor differences in opinion, consistent and stable repetition in data analysis processes, and the ability to avoid errors related to input data and missing data. These results indicate that the oil company has successfully managed oil exploration and exploitation activities while considering various sustainability aspects, including environmental, social, economic, as well as technological and institutional legal aspects.

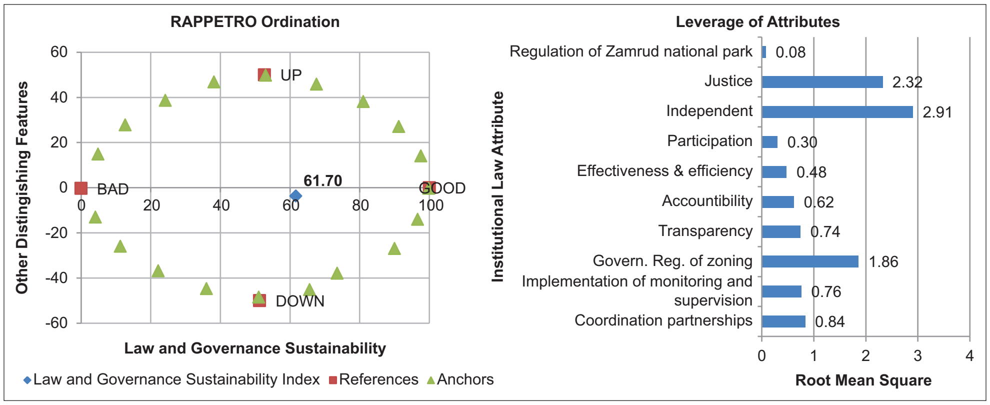
Accuracy testing involved examining stress values and coefficient of determination (R2). Analysis of stress values and R2 was conducted to evaluate whether additional attributes are necessary, while also assessing the accuracy of the dimensions studied against real-world scenarios. Table 3 presents the results of the stress values and coefficient of determination study. The table indicates that all attributes investigated for the sustainability of oil field management are considered accurate and reliable, as the stress values range from 0.13 to 0.15, which is below the established threshold (<0.25), with values <0.25 considered preferable. Meanwhile, the coefficient of determination (R2) is relatively high in each dimension and multidimensional, particularly at 95% (close to 1). Therefore, both of these statistical parameters indicate that all attributes used in each dimension are sufficient to describe the sustainability of oil field management. Thus, the model for estimating sustainability indices is deemed suitable for application.

The findings are in line with the Brundtland Commission, a global commission on environment and development, which has been using the term sustainable development since 1987. Sustainability is defined as a series of actions taken to meet current needs without sacrificing opportunities for the future. Sustainable development entails the ability to meet societal needs by developing the economy with minimal impact on the environment. In the context of hydrocarbon processing, sustainability in oil and gas management refers to the process of managing oil and gas resources, investments, and available technologies to maintain and optimize operations for safety, reliability, higher efficiency, and environmental and social awareness. Energy management or sustainable energy practices in the context of oil and gas

**Table 3: Stress and $R^2$ values for petroleum field management**

| Dimensions | Sustainability index (%) | Category | Stress | $R^2$ (%) |
|---|---|---|---|---|
| Ecological dimension | 64.07 | Moderately sustainable | 0.14 | 95 |
| Economic dimension | 57.72 | Moderately sustainable | 0.14 | 95 |
| Social dimension | 52.91 | Moderately sustainable | 0.14 | 95 |
| Technological dimension | 64.44 | Moderately sustainable | 0.13 | 95 |
| Legal dimension | 61.70 | Moderately sustainable | 0.15 | 95 |

**Figure 7:** Index and attributes for the legal sustainability of oil field management




management in Indonesia encompass several key aspects that support sustainable development goals. Through an integrated and sustainable approach, oil and gas management in Indonesia can positively contribute to inclusive economic development and sustainable environmental practices.

## 4. CONCLUSION

The research findings highlight the importance of sustainable energy practices in the context of oil and gas field management. RAP-Petro analysis indicates that sustainability across all dimensions of oil and gas operations exceeds the threshold of 50.01, depicting a strong commitment to effective implementation. This underscores not only ecological aspects but also considerations for economic, socio-cultural, technological, and institutional legal impacts. To sustain oil and gas activities, continuous improvement in sustainable management efforts is crucial. Leveraged attributes identified as significantly influencing the sustainability of oil field management in the Zamrud National Park conservation area encompass various factors. These include tree species density, forest area, protected wildlife, vegetation diversity, canal water quality, equity ownership, infrastructure development, domestic component level, business potential, revenue sharing contributions from oil and gas, employee income, workplace accidents, community support, conflicts, workforce competence, public facility enhancements, toxic waste management, collection stations, canal water management, waste mud management, drilling technology, reserves/production, production equipment, produced water management, independence, justice, zoning, stakeholder collaboration, monitoring application, and supervision.

To maintain this sustainability, sustainable energy management becomes key. This includes optimizing energy usage during exploration and exploitation processes, implementing environmentally friendly technologies in drilling and production, and efficiently managing waste and produced water. Factors such as toxic waste management, efficient drilling technology use, and efforts to reduce environmental impacts like leaks or canal water quality degradation are prioritized. Moreover, it's important to consider social aspects such as contributions to the local community, workplace safety, and community support in the oil field management process. Sustainable energy management also involves efforts to enhance energy independence and fairness in distributing economic benefits from oil and gas activities. Collaboration with all stakeholders, including government, oil companies, and local communities, is necessary to develop policies that effectively promote these practices. Thus, prioritizing sustainable energy management not only supports operational sustainability but also provides long-term benefits to the environment, economy, and local communities around oil and gas fields.

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