Analysis of Sustainability Variables in Revegetation of Ex-Oil and Gas Mining Operation

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ABSTRAK

Revegetasi setelah operasi penambangan minyak bumi merupakan masalah yang kompleks dan memiliki banyak aspek yang membutuhkan pertimbangan yang cermat terhadap faktor-faktor keberlanjutan untuk memastikan keberhasilan jangka panjang. PT. Pertamina Hulu Rokan telah menjalankan tanggung jawab lingkungannya dengan serius dan telah memulihkan lahan bekas tambang melalui upaya penanaman kembali di lokasi bekas sumur, bekas fasilitas produksi, dan bekas tempat tanah galian. Hal ini sangat penting untuk keberlanjutan lingkungan, terutama setelah operasi penambangan minyak dan gas. Penelitian ini bertujuan mengidentifikasi variabel-variabel penting dalam menjaga keberlangsungan kegiatan revegetasi di PT. Pertamina Hulu Rokan dengan cara mendeskripsikan intensitas pengaruh dan hubungan saling ketergantungan antar variabel serta mengelompokkannya dari yang paling berpengaruh sampai yang paling tidak berpengaruh. *Focus Group Discussion* (FGD) digunakan untuk mengumpulkan data dan pendekatan MICMAC untuk menganalisis hubungan antar variabel. Penelitian ini telah mengidentifikasi 13 variabel ekologi, sosialekonomi, dan mitigasi konflik yang berperan penting dalam kegiatan revegetasi lahan. Berdasarkan hasil penelitian, hubungan antara variabel-variabel tersebut telah diperoleh dengan menyoroti indikator-indikator kunci yang memicu upaya revegetasi berkelanjutan, yaitu variabel-variabel seperti envreg, amdal, *local business development* (lbd), dan relasi. Variabel lbd memiliki pengaruh yang kuat terhadap variabel kesejahteraan, amdal, dan variabel pada variabel lain sangat mempengaruhi citra peerusahaan. Upaya revegetasi lahan pasca tambang di PT. Pertamina Hulu Rokan menunjukkan komitmen perusahaan terhadap keberlanjutan lingkungan. Dengan mempertimbangkan variabel-variabel keberlanjutan dalam proses revegetasi setelah operasi penambangan minyak bumi, PT. PHR memastikan bahwa upaya rehabilitasi yang dilakukan dapat memulihkan lahan sekaligus mempromosikan praktik-praktik berkelanjutan dan memberikan manfaat bagi masyarakat setempat.

Kata kunci: Keberlanjutan, Revegetasi, Pertambangan, MICMAC, Strategi

ABSTRACT

Revegetation after petroleum mining operations is a complex and multifaceted issue that requires careful consideration of sustainability factors to ensure long-term success. PT Pertamina Hulu Rokan has taken its environmental responsibilities seriously and has restored ex-mining land through replanting efforts at ex-well sites, ex-production facilities, and ex-borrow pits. This is important for environmental sustainability, especially after mining oil and gas. This study aims to identify important variables in maintaining the sustainability of revegetation activities at PT Pertamina Hulu Rokan by describing the intensity of influence and interdependence between variables and grouping them from the most influential to the least influential. Focus group discussions (FGDs) were used to collect data, and the MICMAC approach was used to analyze the relationships between variables. This research has identified 13 ecological, socioeconomic, and conflict mitigation variables that are important in land revegetation activities. Based on the results, the relationships between these variables have been derived by highlighting the key indicators that trigger sustainable revegetation efforts, namely variables such as envreg, amdal, local business development (lbd), and relationship. The lbd variable strongly influences the welfare variable, amdal, and the other variables strongly influence the company's image. Post-mining land revegetation efforts at PT Pertamina Hulu Rokan demonstrate the company's commitment to environmental sustainability. By considering sustainability variables in the revegetation process after petroleum mining operations, PT PHR ensures that its rehabilitation efforts can restore land while promoting sustainable practices and providing benefits to local communities.

Keywords: Sustainability, Revegetation, Mining, MICMAC, Strategy

1. INTRODUCTION

PT Pertamina Hulu Rokan has restored ex-mining lands by revegetation. This activity is carried out as a form of environmental responsibility after the end of the mining operation period. Revegetation occurs in ex-well pads, ex-production facilities, and ex-borrow pits. Land revegetation is essential to environmental sustainability efforts (Buta *et al*., 2019), particularly after oil and gas mining operations.

The sustainability of land revegetation after petroleum mining operations is a complex and multifaceted issue encompassing various ecological, economic, and social dimensions. By analysing essential sustainability factors, we can evaluate land revegetation efficiency and enduring sustainability following petroleum mining activities (Yu *et al*., 2020). These variables include the ecological aspect, economic aspect, and social aspect. The ecological aspect examines how the revegetation process restores biodiversity, promotes native plant and animal species, and improves ecosystem stability (Zhang *et al*., 2018; Valkó *et al*., 2023). The economic aspect assesses the economic feasibility and cost-effectiveness of the land revegetation process, considering factors such as the long-term value of restored ecosystems, potential economic benefits from the rehabilitated land, and the overall return on investment (Wainaina *et al*., 2020; Setiawan *et al*., 2021). The social aspect evaluates the impact of land revegetation on local communities, including their engagement and participation in the restoration process, potential job creation, and social cohesion and well-being (Erbaugh & Oldekop, 2018; Ahmadreza & Kheyroddin, 2023). Other factors to consider for sustainability also involve implementing sustainable land management methods when revegetating, which includes reducing soil erosion and employing sustainable water management practices (Dharmawan *et al*., 2023).

It is important to assess the sustainability of revegetation activity to ensure the long-term success of land revegetation efforts after petroleum mining operations. With a thorough analysis of the sustainability variables, it is easier to determine the overall effectiveness and long-term viability of the land revegetation process (Lestari *et al*., 2022; Zhao *et al*., 2022). This analysis will provide valuable insights into sustainability's ecological, economic, and social dimensions in land revegetation. Additionally, evaluating sustainability variables will help identify potential negative impacts on the natural and social environment, allowing corrective measures to be implemented (Bhatti & Sulaiman, 2023). Ultimately, conducting a comprehensive analysis of sustainability variables in land revegetation after petroleum mining operations is crucial for ensuring the affected areas and communities' ecological resilience, economic viability, and social well-being. Furthermore, this analysis will contribute to the larger goal of transitioning towards a more sustainable and environmentally conscious energy industry. By
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considering sustainability variables in the revegetation process after petroleum mining operations, we can ensure that the rehabilitation efforts are not only about restoring the land but also about promoting sustainable practices and benefiting local communities (Budiman *et al*., 2020 ; Yuwati *et al*., 2021). This research seeks to determine key factors that contribute to the sustainability of revegetation program at PT Pertamina Hulu Rokan by analyzing the strength of their impact, the relationships between them, and categorizing them based on their level of influence.

2. METHODS

This research was conducted in the post-mining land revegetation area of PT Pertamina Hulu Rokan, Riau Province (Figure 1).
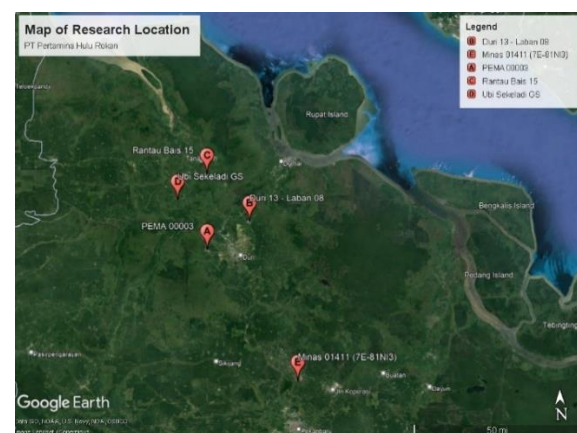

Figure 1. Research Location

This study used a prospective structural paradigm to explore the structure, dynamics, and network of interrelationships between variables considered most important in determining essential variables in revegetation activities. Data was collected using the Focus Group Discussion (FGD) method to determine influential variables. Based on the results of FGDs with relevant stakeholders, 13 elements or variables representing ecological, economic, social, technological, and institutional dimensions were identified. Direct observations in the field include land characteristics, plant conditions, and forms of community involvement in revegetation activities.

Systematic problem-solving can rely on analytical thinking with the MICMAC approach (Godet *et al*., 1999; Bakrie *et al*., 2023). Several steps must be taken to determine and map the key variables in using MICMAC. It starts with formulating the problem (Stratigea & Giaoutzi, 2013), then identifies internal and external variables. In the next stage, MICMAC analyses the relationship between variables and boots the relationship (de Almeida & de Moraes, 2013; Chatziioannou *et al*. 2023).

In MICMAC, variables are grouped into four quadrants based on dependency and influence categories, as shown in Figure 2.
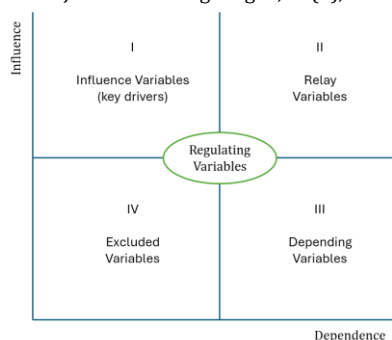
Figure 2. Variable Mapping in MICMAC (Fauzi, 2019)

3. RESULT AND DISCUSSION

Based on the results of FGDs with stakeholders, 13 variables or elements representing ecological, socialeconomic, and conflict mitigation aspects were obtained. These 13 variables concentrate on the status of revegetation sustainability in the post-operation area of PT Pertamina Hulu Rokan (Table 1).

The analysis result of MICMAC in variable mapping, as shown in Figure 3. Two ecological indicators, namely envreg and amdal, and two socioeconomic indicators, namely local business development (lbd) and relation, are in the influence variable or driver variable quadrant. These four items are the main indicators that trigger the implementation of the sustainable revegetation program.

Wahyuda *et al*. (2023) emphasised the importance of clearly outlined and scientifically rigorous principles for achieving a revegetation initiative. Without established protocols or proper procedure, the efficacy and ultimate triumph of a revegetation program may be impeded by diverse obstacles. Community participation is indeed a crucial factor in the success of revegetation programs. Implementing Environmental Management Systems (EMS) within companies is increasingly recognised as an important step towards achieving sustainable development and operational efficiency (Muzanni *et al*., 2022). Adopting an EMS, like an amdal, is a reference for PT. Pertamina Hulu Rokan in implementing their commitment to environmental improvement in their area of operations, guiding them to reduce their ecological footprint and improve their environmental performance. Research shows that the initiation and successful implementation of environmental strategies is significantly influenced by top management commitment, which reflects strategic alignment with environmental sustainability goals. Junanda and Haririah, (2023) mentioned that the involvement of lbd in the planning, implementing, and maintaining revegetation efforts can lead to numerous benefits and enhance the overall effectiveness of such initiatives. Community involvement is critical for the success of reforestation interventions, as communities possess diverse mixes of livelihood assets required for implementation (Rahmat Safe'i *et al*., 2022; N'tambwe Nghonda *et al*., 2023).

In contrast, other ecological variables such as land preparation, ecoprotect, and soil condition are in the dependent quadrant. These indicators are affected variables of other variables. image and environmental policy, which act as relay variables. This suggests that the mentioned variables are highly sensitive and unstable in the process of achieving sustainable revegetation, as any intervention in these variables can have a significant impact on the overall system. Sujanska & Nadanyiova, (2023) emphasised that the impact of a company's environmental commitment on its image is multifaceted and significant, influencing consumer perceptions, corporate reputation, and, ultimately, the company's market position. Sustainability has become crucial to a company's image, with consumers increasingly preferring companies that adopt sustainable practices. The impact of environmental policy on sustainable revegetation is multifaceted, reflecting a complex interplay between policy instruments, ecological outcomes, and socio-economic factors. When effectively implemented, environmental policies can significantly influence the success of revegetation efforts (Vezzoni *et al*., 2023).

Table 1. Variable Identified as Sustainable of Variables

| Long Label	Short Label	Description	Aspect
Environmental policy	envpol	Company commitment and responsibility in sustainablity	ecological
Environmental Regulation	envreg	No standard guidelines in revegetation program (specific regulation)	ecological
Land preparation	landprep	Land preparation is not done properly	ecological
Soil Condition	soil	Soil to be revegetated is less fertile and degraded	ecological
Ecosystem protection	ecosystem	Improving ecosystem protection	ecological
Environmental Impact Assessment	amdal	Obtaining green proper	ecological
limited supervision	supervise	Limited workforce of the supervision team to conduct plant monitoring at each revegetation site	socioeconomic
Local Bussines Development	lbd	Involving local resources as Local Bussines Development (LBD) in program implementation	socioeconomic
A positive image of the company	image	Improve the company's positive image	socioeconomic
Community welfare	welfare	Maintain and improve community welfare	socioeconomic
Destruction of vegetation	disveg	Plant destruction by surrounding communities	conflict mitigation
Relationship	relation	Good relationship between the company and the community	conflict mitigation
Land encroachment	encroach	The occurrence of social conflicts with surrounding communities	conflict mitigation
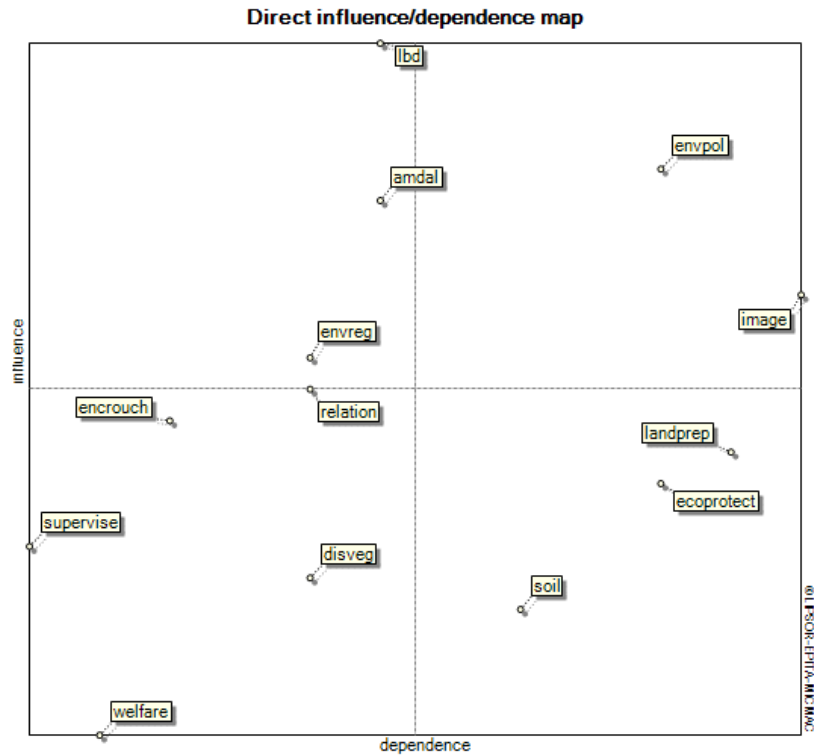
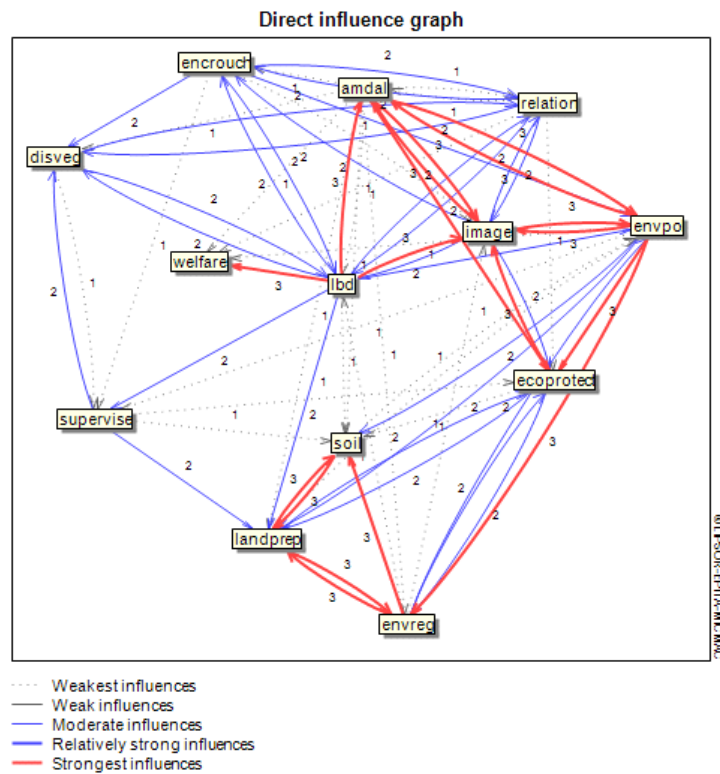**Figure 3.** Map of Sustainability Variables by Influence and Dependency

Figure 4. Direct Influence Relationship Between Sustainability Variables

Other indicators, such as supervision, disturbance to vegetation (disveg), welfare, and land encroachment, are in the autonomous position. Based on indicators position in the 4ᵗʰ quadrant, the indicators relatively little influence on the evaluated system. lthough the disturbance of these four variables is minor in the analysis results, in fact, these four variables can disturb the sustainability of revegetation in the field. This is in line with research from Guan *et al*. (2023) n the influence of weak supervision in the success of revegetation activities, then research by Chardon *et al*. (2018), Brusseau *et al*. (2019), and Erfanian *et al*. (2021) on anthropogenic

disturbances in the implementation of revegetation activities.

Figure 4 shows the network of direct influence between variables. As shown in the figure, the lbd variable has a powerful influence on the welfare variable, amdal variable, and image variable. While variables such as envpol, amdal, image, ecoprotect, land prep, envreg, and soil strongly influence each other. Similarly, the results of this study are supported by findings from Rahmawan (2020) regarding the involvement of local business development (lbd), Rusdiana & Setiadi (2019) regarding land preparation as a determining variable in the success of land revegetation.

Figure 5 shows the indirect influence relationship between variables. The number on each arrow in Figure 5 shows the degree or rating of influence obtained through iteration of the Boolean matrix. In Figure 5, a powerful indirect effect occurs on the lbd variable to the image variable. This shows the influence of lbd on other variables, which will then indirectly have a significant effect on the image. Figure 5 also indicates that the ecology variable dominates the strong indirect effect, while the conflict mitigation variable shows a relatively weak indirect effect.

Figures 6(a) and 6(b) show the changes in variable ranking based on influence and dependence. These changes illustrate the position of variables in the initial condition (MDI matrix) and after Boolean iteration with MDII. Figure 6(a) shows a shift in the order of influential variables such as envpol, envreg, landprap, and supervise (red line). This occurred after iteration when indirect influence factors were considered. On the other hand, some variables such as envreg, relation, encrouch, ecoprotect, and disveg increased in order.
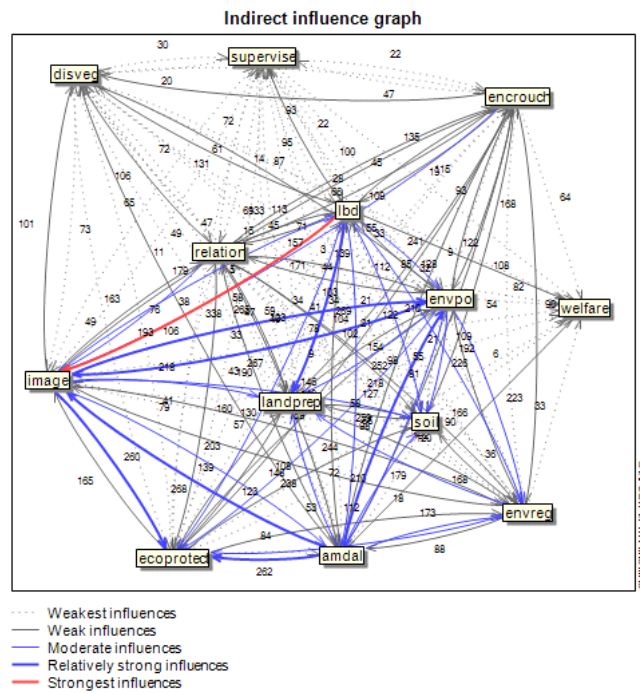

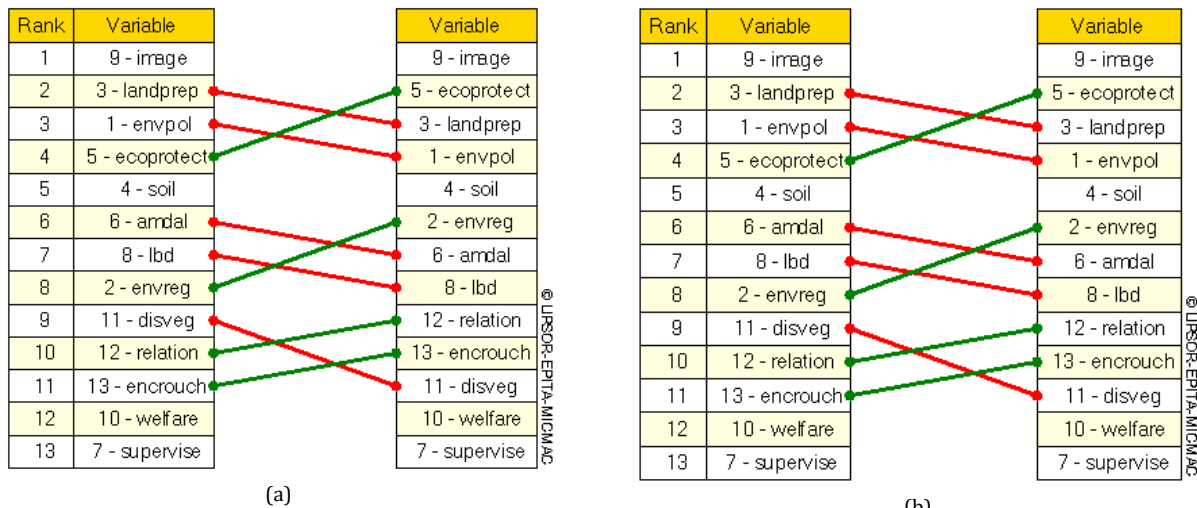**Figure 5.** Indirect Influence Relationship Between Sustainability Variables

(a)

(b)

Figure 6. Variable Ranking Based on Influence (a) and Variable Ranking Based on Dependence (b)
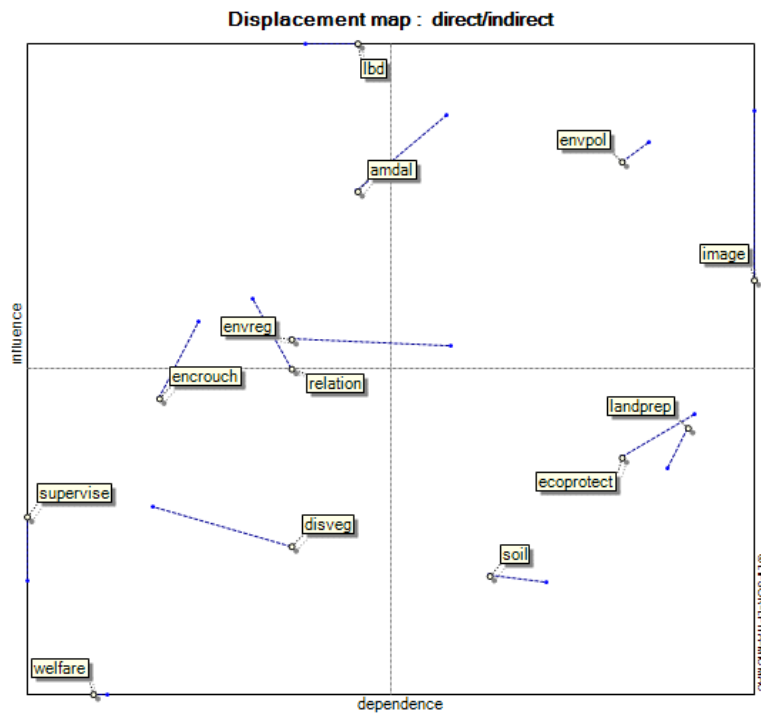
Figure 7. Displacement Map Between Variables from Direct to Indirect Effects

Regarding dependence in Figure 6(b), one primary variable, namely image, soil, welfare, and supervise, consistently did not change its position as a dependence variable. Some variables, such as landprep, envpol, amdal, and lbd, decreased by one level after MDII iteration, while the disveg variable decreased by two levels. Several other variables such as ecoprotect, envreg, relation, and encrouch, experienced an increase in rank after accounting for indirect effects. The shift of these variables due to the indirect impacts can be seen in Figure 7.

In Figure 7, the dashed lines show the variables' position change from initial to final positions after accounting for indirect effects. Variables are shifted within the same quadrant, and some variables move to other quadrants. For example, the variables amdal and envreg shifted sharply to the dependence quadrant, and the variable encrouch moved sharply to the influence quadrant.

4. CONCLUSION

13 variables have been identified as essential representing ecological, socialeconomic, and conflict aspects on the status of revegetation sustainability (environmental policy, environmental regulation, land preparation, soil condition, ecosystem protection, environmental impact assessment, limited supervision, local business development, image of the company, community welfare, destruction of vegetation, relationship, and land encroachment). The key variables that trigger sustainable revegetation and sensitive indicators to intervention, namely environmental regulation in the company internal (envreg), company's commitment in amdal (amdal), local empowerment (lbd), and r harmonising

the company's relationship with the community and other stakeholders (relation).

The findings emphasised the importance of considering sustainability indicators in land revegetation after petroleum mining operations to ensure ecological resilience, economic viability, and social well-being. In addition, it is important to transition towards more sustainable and environmentally conscious energy industry practices by integrating sustainability variables in the revegetation process.

REFERENCES

Ahmadreza, S., & Kheyroddin, R., (2023), Building Resilience in Cultural Landscapes: Exploring the Role of Transdisciplinary and Participatory Planning in the Recovery of the Shushtar Historical Hydraulic System *Sustainability*, 15 (13).

Bakrie, B., Sirnawati, E., Rohaeni, E. S., Hutahaean, L., Santoso, A. D., Wasito, W., & Indrawanto, C., (2023), Sustainability Analysis of Intensive Duck Farming System in Sliyeg District, Indonesia: MDS and MICMAC Analysis Approach, *International Journal of Sustainable Development and Planning*, *18*(10), 3181–3193.

Bhatti, U., & Sulaiman, N., (2023), The Impact of Sustainability Practices on Share Performance with Mediation of Board Members Experience: A Study on Malaysian Listed Companies, *International Journal of Financial Studies*, 11(1), 4.

Brusseau, M. L., Glenn, E. P., & Pepper, I. L., (2019), Reclamation and Restoration of Disturbed Systems, *Environmental and Pollution Science*. Elsevier, pp. 355–376.

Budiman, I., Bastoni, Sari, E. N. N., Hadi, E. E., Asmaliyah, Siahaan, H., Januar, R., & Hapsari, R. D., (2020), Progress of paludiculture projects in supporting

peatland ecosystem restoration in Indonesia, *Global Ecology and Conservation*, *23*, e01084.

Buta, M., Blaga, G., Paulette, L., Păcurar, I., Roșca, S., Borsai, O., Grecu, F., Sînziana, P. E., & Negrușier, C., (2019), Soil Reclamation of Abandoned Mine Lands by Revegetation in Northwestern Part of Transylvania: A 40-Year Retrospective Study, *Sustainability*, 11(12), 3393.

Chardon, N. I., Wipf, S., Rixen, C., Beilstein, A., & Doak, D. F., (2018), Local trampling disturbance effects on alpine plant populations and communities: Negative implications for climate change vulnerability, *Ecology and Evolution*, *8*(16), 7921–7935.

Chatziioannou, I., Nikitas, A., Tzouras, P. G., Bakogiannis, E., Alvarez-Icaza, L., Chias-Becerril, L., Karolemeas, C., Tsigdinos, S., Wallgren, P., & Rexfelt, O., (2023), Ranking sustainable urban mobility indicators and their matching transport policies to support liveable city Futures: A MICMAC approach, *Transportation Research Interdisciplinary Perspectives*, 18, 100788.

de Almeida, M. F. L., & de Moraes, C. A. C., (2013), Diffusion of emerging technologies for sustainable development: Prospective assessment for public policies, *Journal of Technology Management and Innovation*, 8(2), 228–238.

Dharmawan, I. W., Pratiwi, Siregar, C. A., Narendra, B. H., Undaharta, N. K., Sitepu, B. S., Sukmana, A., Wiratmoko, M. D., Abywijaya, I. K., & Sari, N., (2023), Implementation of Soil and Water Conservation in Indonesia and Its Impacts on Biodiversity, Hydrology, Soil Erosion and Microclimate, *Applied Sciences*, 13(13), 7648

Erbaugh, J. T., & Oldekop, J. A., (2018), Forest landscape restoration for livelihoods and well-being, *Current Opinion in Environmental Sustainability*, 32, 76–83.

Erfanian, M. B., Alatalo, J. M., & Ejtehadi, H., (2021), Severe vegetation degradation associated with different disturbance types in a poorly managed urban recreation destination in Iran. *Scientific Reports*, *11*(1), 19695.

Godet, M., Arcade, J., Meunier, F., & Roubelat, F., (1999), *Structural Analysis with The MICMAC Method & Actors's Strategy with MACTOR Method*.

Guan, Y., Wang, J., Zhou, W., Bai, Z., & Cao, Y., (2023), Delimiting supervision zones to inform the revision of land reclamation management modes in coal mining areas: A perspective from the succession characteristics of rehabilitated vegetation, *Land Use Policy*, 131, 106729.

Junanda, A., & Harirah, Z. M., (2023), Partisipasi Masyarakat Dalam Mendukung Kebijakan Pengendalian Kebakaran Hutan Dan Lahan di Kabupaten Rokan Hilir Tahun 2019-2020, *Jurnal Sosio-Komunika*, 2(1), 295–313.

Lestari, K. G., Budi, S. W., & Suryaningtyas, D. T., (2022), The impact of revegetation activities in various post-mining lands in Indonesia (study of literature), *IOP Conference Series: Earth and Environmental Science*, 959(1), 12038.

Muzanni, A., Soesilo, T. E. B., Martono, D. N., Hamzah, U. S., Berkademi, W., & Febraldo, D., (2022), Review of Environmental Management System Implementation in The Oil and Gas Company in Indonesia, *IOP Conference Series: Earth and Environmental Science*, 1111(1), 012018.

N'tambwe Nghonda, D., Muteya, H. K., Kashiki, B. K. W. N.,

Sambiéni, K. R., Malaisse, F., Sikuzani, Y. U., Kalenga, W. M., & Bogaert, J., (2023), Towards an Inclusive Approach to Forest Management: Highlight of the Perception and Participation of Local Communities in the Management of miombo Woodlands around Lubumbashi (Haut-Katanga, D.R. Congo), *Forests*, 14(4), 687.

Rahmat Safe'i, Leo Muhammad Widodo, Gunardi Djoko Winarno, & Slamet Budi Yuwono., (2022), Community Participation Program in Forest and Land Rehabilitation in the Batutegi Forest Management Unit, *Journal of Sylva Indonesiana*, 5(02). 93-102.

Rahmawan, A. D., (2020), Keterbilatan Masyarakat Lokal Dalam Restorasi Kawasan Pasca Tambang Timah Oleh PT. Refined Bangka Tin Di Desa Penyamun, *Jurnal Sosiologi Nusantara*, 6(2), 123.

Rusdiana, O., & Setiadi, A., (2019), The Evaluation of the Success of Plant Revegetation in Post Coal Mining Block M1W PT Jorong Barutama Greston, South Kalimantan, *Jurnal Silvikultur Tropika*, 10(03), 125–132.

Setiawan, I. E., Zhang, Z., Corder, G., & Matsubae, K., (2021), Evaluation of Environmental and Economic Benefits of Land Reclamation in the Indonesian Coal Mining Industry. *Resources* 10(6), 60.

Sujanska, L., & Nadanyiova, M. (2023). Sustainable Marketing and its Impact on the Image of the Company. *Marketing and Management of Innovations*, 14(2), 51–57.

Valkó, O., Fekete, R., Molnár V, A., Halassy, M., & Deák, B., (2023), Roadside grassland restoration: Challenges and opportunities in the UN decade on ecosystem restoration, *Current Opinion in Environmental Science & Health*, 34, 100490.

Vezzoni, R., Sijtsma, F., & Vihinen, H., (2023), Designing effective environmental policy mixes in the UN Decade on ecosystem restoration, *Ecosystem Services*, 62, 101541.

Wahyuda, W., Arifin, Y. F., & Hatta, G. M., (2023). Evaluasi Kualitas Hidup dan Pertumbuhan Tanaman Revegetasi di Areal Pascatambang Kabupaten Tanah Laut, *Jurnal Sylva Scienteae*, 6(3),458.

Wainaina, P., Minang, P. A., Gituku, E., & Duguma, L., (2020), Cost-Benefit Analysis of Landscape Restoration: A Stocktake. *Land*, 9(11), 465.

Yu, X., Mu, C., & Zhang, D., (2020), Assessment of Land Reclamation Benefits in Mining Areas Using Fuzzy Comprehensive Evaluation, *Sustainability*, 12(5), 2015.

Yuwati, T. W., Rachmanadi, D., Pratiwi, Turjaman, M., Indrajaya, Y., Nugroho, H. Y., Qirom, M. A., Narendra, B. H., Winarno, B., Lestari, S., Santosa, P. B., Adi, R. N., Savitri, E., Putra, P. B., Wahyuningtyas, R. S., Prayudyaningsih, R., Halwany, W., Nasrul, B., Bastoni, & Mendham, D., (2021), Restoration of Degraded Tropical Peatland in Indonesia: A Review, *Land*, 10(11), 1170.

Zhang, Q., Zhang, T., & Liu, X., (2018), Index System to Evaluate the Quarries Ecological Restoration, *Sustainability*, 10(3), 619.

Zhao, F., Wu, Y., Yin, X., Alexandrov, G., & Qiu, L., (2022), Toward Sustainable Revegetation in the Loess Plateau Using Coupled Water and Carbon Management, *Engineering*, 15, 143–153.