Eco-Efficiency in the Era of Sustainability: Mapping the Intellectual Landscape of Green Operations Research

Fitrina Lestari[1], Agus Rahayu[2],
Puspo Dewi Dirgantari[3], Lili Adi Wibowo[4],
Neni Nuraeni[5], Wiji Safitri[6]

[1,2,3,4,5,6]Universitas Pendidikan Indonesia, Bandung, Indonesia
fitrinalestari@upi.edu

Abstract. This study examines the development of eco-efficiency and green operations research from 2015 to 2025 using a bibliometric approach. It aims to identify publication trends, map dominant research themes, and visualize collaboration networks within the field. Data were retrieved from the Scopus database and limited to English-language journal articles, resulting in a final corpus of 388 documents. Co-occurrence analysis, citation analysis, and thematic mapping were employed to capture the intellectual structure and thematic evolution of the literature. The findings show a steady increase in publications from 2015 to 2020, with notable peaks in 2019 and 2020, indicating growing scholarly attention to environmental efficiency across sectors. However, the decline observed in 2025 may reflect publication indexing delays or a temporary shift toward more urgent research agendas, while future publication growth remains possible. Conceptually, the field has moved from theoretical discussions toward more practical and data-driven approaches, with life cycle assessment and data envelopment analysis becoming central analytical tools. Thematic mapping identifies eco-efficiency, environmental management, and sustainable development as dominant themes, while circular economy and eco-innovation are gaining momentum. The study also highlights the contribution of leading institutions, including Tsinghua University, to international collaboration. Finally, it reveals limited research on eco-efficiency in small and medium enterprises in developing countries, suggesting the need for more accessible and adaptable sustainability models.

Keywords: Eco-Efficiency, Green Operations, Sustainability, Bibliometric.

1. Introduction

Sustainability has become a central issue as industries face increasing pressure to balance economic growth with environmental responsibility. Eco-efficiency offers an approach for creating economic value while minimizing environmental impact through efficient resource use and the reduction of waste, emissions, and pollution [1,2]. Closely related to this concept, green operations integrate environmentally responsible practices into production systems, supply chain management, resource use, and waste reduction [3,4]. The relevance of eco-efficiency and green operations has increased due to envi-

© The Author(s) 2026
R. Hurriyati et al. (eds.), *Proceedings of the 10th Global Conference on Business, Management, and Entrepreneurship (GCBME 2025)*, Advances in Economics, Business and Management Research 407,
https://doi.org/10.2991/978-94-6239-819-1_89

ronmental regulation, climate change, and the need for more sustainable industrial systems. Previous studies show that environmental policy can encourage firms and regions to improve ecological and operational efficiency [5,6]. At the firm level, eco-efficiency supports cleaner production, resource productivity, environmental performance, and long-term competitiveness [7,1].

Theoretically, eco-efficiency and green operations are linked to sustainability-oriented operations, green supply chain management, circular economy, and eco-innovation, which explain how firms integrate environmental responsibility into operations, supply chains, innovation, and value creation [3,8,9,10]. However, the literature remains fragmented, with many studies focusing on specific sectors, regions, or methods. Broader mapping of publication trends, intellectual structure, thematic evolution, collaboration patterns, and research gaps remains limited. Therefore, this study maps eco-efficiency and green operations research from 2015 to 2025 using bibliometric analysis, with particular attention to underexplored issues such as eco-efficiency in SMEs in developing countries [8].

2. Methods

This study employed a bibliometric approach to examine eco-efficiency and green operations research from 2015 to 2025. This method enables systematic mapping of publication trends, keyword relationships, influential sources, collaboration patterns, and thematic structures within a research field. It is relevant because eco-efficiency studies increasingly use quantitative and comparative methods to evaluate environmental efficiency, operational performance, and sustainability development across sectors and regions [11,12]. Data were retrieved from Scopus using keywords related to eco-efficiency and green operations. The inclusion criteria were journal articles, final-stage publications, English-language documents, and publications within 2015–2025. After screening, 388 documents were included in the final dataset. The document selection process is presented in Figure 1.

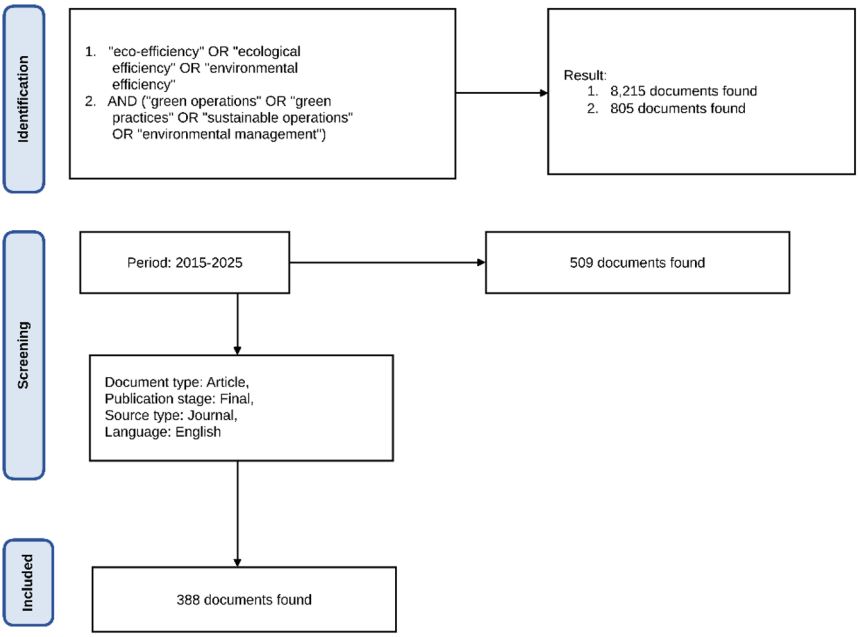

Fig. 1 PRISMA flow diagram of the study selection process

The data were analyzed using VOSviewer and Biblioshiny through co-occurrence analysis, citation analysis, collaboration network analysis, and thematic mapping. These techniques were used to identify keyword relationships, influential publications and sources, collaboration networks, and research themes categorized as motor, basic, niche, and emerging themes. They are consistent with the increasing use of data-driven methods in eco-efficiency studies, particularly life cycle assessment and data envelopment analysis [13,14]. This study is limited to Scopus-indexed, English-language journal articles; thus, studies from other databases, languages, and publication types may not be captured. Citation analysis may also favor older publications, while 2025 data should be interpreted cautiously due to indexing delays.

3. Results And Discussion

3.1 The Publication Trends

The analysis shows that eco-efficiency and green operations research developed dynamically during 2015–2025. The dataset includes 388 documents from 151 sources, with an average document age of 5.25 years and 32.44 citations per document. It involves 1,232 authors, with only 19 single-authored documents, indicating strong collaboration, as reflected in 3.81 authors per document and 30.93% international collaboration. Publications increased from 2015 to 2020, with strong publication intensity in 2019 and 2020. The highest number of publications occurred in 2023 with 48 articles, followed by a decline in 2024 and 2025. The decline in 2025 should be interpreted cautiously because the data only covered the first trimester and may be affected by

indexing delays. Overall, this trend suggests that eco-efficiency and green operations remain important research areas as environmental efficiency and low-carbon development continue to shape sustainability studies [11,5].

3.2. Keyword Co-Occurrence and Thematic Structure

The keyword co-occurrence network in Figure 2 shows that eco-efficiency, environmental management, sustainable development, life cycle assessment, data envelopment analysis, environmental performance, and energy efficiency are central themes. These connections indicate that the field increasingly focuses on measuring and improving environmental and operational performance through data-driven methods.

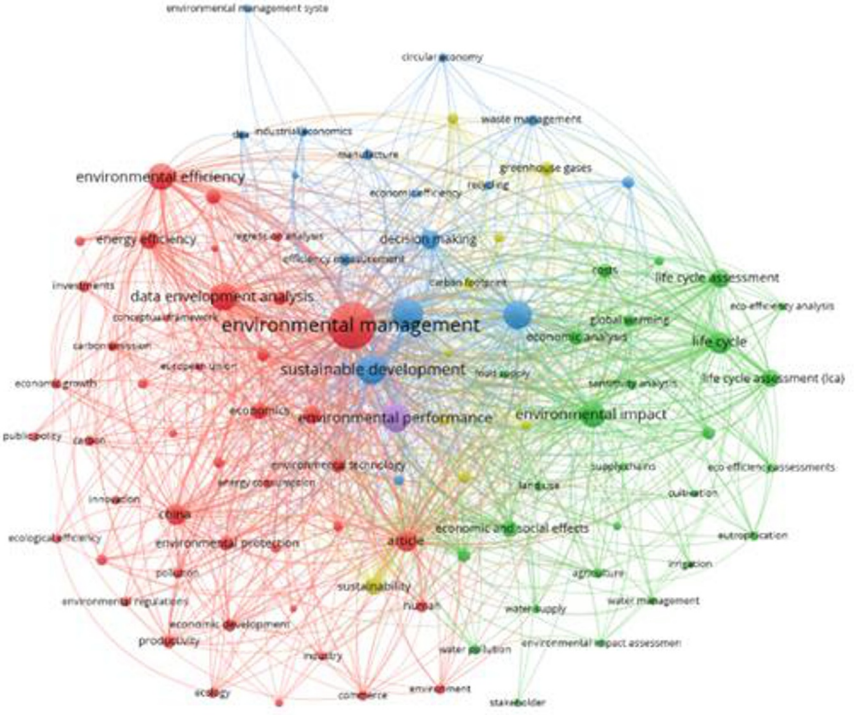

Fig. 2. Co-occurrence Visualization Results.

Life cycle assessment and data envelopment analysis appear as key methodological tools for evaluating eco-efficiency in agricultural systems, production processes, and environmental performance assessment [13,14]. This pattern shows that the field has moved from broad sustainability discussions toward more specific and measurable approaches.

Thematic mapping in Figure 3 classifies environmental performance as a motor theme. Eco-efficiency, life cycle assessment, environmental management, and data envelopment analysis appear as basic themes, indicating their central but still developing role in the field. Eco-innovation falls in the emerging or declining quadrant, while niche themes are represented by topics such as carbon footprint reduction and eco-efficiency

assessment. The position of data envelopment analysis and environmental efficiency among the basic themes shows strong attention to quantitative performance measurement, whereas eco-innovation reflects emerging attention to sustainability-driven innovation [8,9,10].

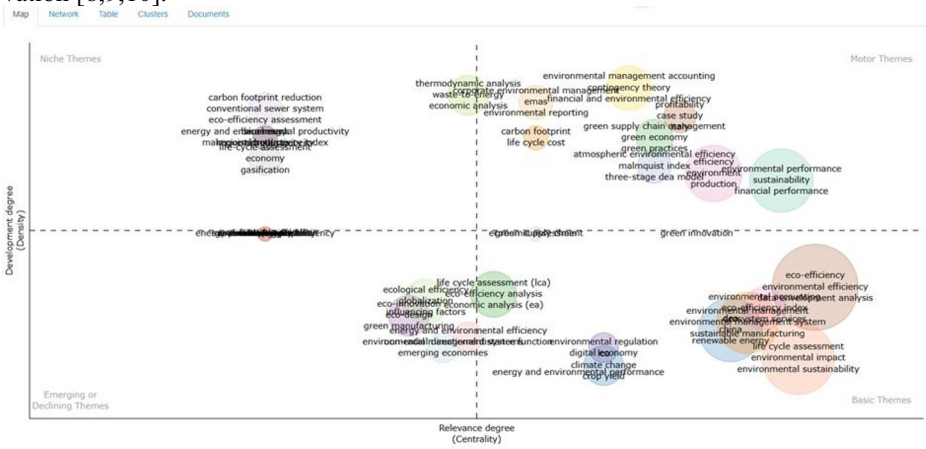

Fig. 3. Thematic Map

The findings confirm that eco-efficiency and green operations remain highly relevant in sustainability research. The increase in publications from 2015 to 2020 reflects growing scholarly attention to environmental efficiency, cleaner production, low-carbon development, and sustainable industrial systems [1,5]. Although publications declined in 2025, this should not be read as a weakening trend because the data may still be incomplete due to indexing delays.

Conceptually, the field appears to emphasize practical and data-driven applications. The prominence of life cycle assessment and data envelopment analysis shows that researchers are focusing on measuring environmental impact, comparing operational efficiency, and identifying improvement opportunities in industrial systems [14,16,17]. The strong connection among eco-efficiency, environmental management, and sustainable development confirms that this field is grounded in sustainability-oriented operational decision-making.

The dominance of journals such as the Journal of Cleaner Production, Sustainability, and Resources, Conservation and Recycling indicates that the literature is closely related to cleaner production, resource conservation, circular economy, and sustainable operations. These studies show that eco-efficiency is increasingly used to balance economic and environmental outcomes in firms and value chains [3,10]. Collaboration patterns also show the role of leading institutions and international networks, especially in countries with strong industrial development and environmental policy pressure [11,5].

However, eco-efficiency in SMEs, particularly in developing countries, remains underexplored. This may occur because many eco-efficiency studies rely on tools such as life cycle assessment and data envelopment analysis, which require reliable data, technical expertise, and financial resources. In contrast, SMEs often face limited managerial capacity, weak environmental data systems, restricted access to green technology, and

financial constraints. Existing SME studies suggest that eco-efficiency and eco-innovation require more accessible and context-sensitive approaches to support sustainability adoption in smaller firms [15]. Thus, simpler and affordable eco-efficiency models are needed to help SMEs reduce waste, improve resource productivity, lower costs, and strengthen competitiveness.

This study contributes by mapping the intellectual development of eco-efficiency and green operations research and identifying its dominant, emerging, and underexplored themes. Practically, eco-efficiency can help firms improve resource productivity and competitiveness, while policymakers should support SMEs through green training, incentives, appropriate technology access, and simplified environmental indicators. However, this study is limited to Scopus-indexed, English-language journal articles, which may exclude relevant studies from other databases, languages, and publication types. Citation analysis may also favor older publications, while 2025 data may be incomplete due to indexing delays. Future research should expand database coverage, combine bibliometric analysis with systematic review, and develop affordable, context-sensitive eco-efficiency models for SMEs in developing countries.

4. Conclusion

This study shows that eco-efficiency and green operations research has developed significantly over the last decade, driven by sustainability, environmental efficiency, and cleaner production concerns. The field has shifted toward practical and data-driven applications, with life cycle assessment, data envelopment analysis, and environmental performance as central themes and eco-innovation as an emerging area [9,14,17]. However, eco-efficiency in SMEs, particularly in developing countries, remains limited. Despite its limitations, this study provides a focused knowledge map and reinforces eco-efficiency as both a conceptual framework and a strategic tool for developing adaptive, efficient, and sustainable industrial operations.

References

1. Ozturk, E., Koseoglu, H., Karaboyaci, M., Yigit, N.O., Yetis, U., Kitis, M.: Sustainable Textile Production: Cleaner Production Assessment/Eco-Efficiency Analysis Study in a Textile Mill. Journal of Cleaner Production 138, 248–263 (2016)
2. Yang, L., Zhang, X.: Assessing Regional Eco-Efficiency from the Perspective of Resource, Environmental and Economic Performance in China: A Bootstrapping Approach in Global Data Envelopment Analysis. Journal of Cleaner Production 173, 100–111 (2018)
3. Carvalho, H., Govindan, K., Azevedo, S.G., Cruz-Machado, V.: Modelling Green and Lean Supply Chains: An Eco-Efficiency Perspective. Resources, Conservation and Recycling 120, 75–87 (2017)
4. Sellitto, M.A., Hermann, F.F., Blezs, A.E., Barbosa-Póvoa, A.P.: Describing and Organizing Green Practices in the Context of Green Supply Chain Management: Case Studies. Resources, Conservation and Recycling 145, 1–10 (2019)

5. Song, M., Zhao, X., Shang, Y.: The Impact of Low-Carbon City Construction on Ecological Efficiency: Empirical Evidence from Quasi-Natural Experiments. Resources, Conservation and Recycling 157 (2020)
6. Yuan, B., Ren, S., Chen, X.: Can Environmental Regulation Promote the Coordinated Development of Economy and Environment in China's Manufacturing Industry? A Panel Data Analysis of 28 Sub-Sectors. Journal of Cleaner Production 149, 11–24 (2017)
7. Lucato, W.C., Vieira, M., Da Silva Santos, J.C.: Eco-Six Sigma: Integration of Environmental Variables into the Six Sigma Technique. Production Planning and Control 26(8), 605–616 (2015)
8. Ceptureanu, S.I., Ceptureanu, E.G., Popescu, D., Orzan, O.A.: Eco-Innovation Capability and Sustainability Driven Innovation Practices in Romanian SMEs. Sustainability 12(17) (2020)
9. Laso, J., García-Herrero, I., Margallo, M., Vázquez-Rowe, I., Fullana, P., Bala, A., Gazulla, C., Irabien, Á., Aldaco, R.: Finding an Economic and Environmental Balance in Value Chains Based on Circular Economy Thinking: An Eco-Efficiency Methodology Applied to the Fish Canning Industry. Resources, Conservation and Recycling 133, 428–437 (2018)
10. Mavi, N.K., Mavi, R.K.: Energy and Environmental Efficiency of OECD Countries in the Context of the Circular Economy: Common Weight Analysis for Malmquist Productivity Index. Journal of Environmental Management 247, 651–661 (2019)
11. Li, F., Ye, S., Chevallier, J., Zhang, J., Kou, G.: Provincial Energy and Environmental Efficiency Analysis of Chinese Transportation Industry with the Fixed-Sum Carbon Emission Constraint. Computers and Industrial Engineering 182 (2023)
12. Wang, Z., Feng, C.: A Performance Evaluation of the Energy, Environmental, and Economic Efficiency and Productivity in China: An Application of Global Data Envelopment Analysis. Applied Energy 147, 617–626 (2015)
13. Rebolledo-Leiva, R., Angulo-Meza, L., Iriarte, A., González-Araya, M.C., Vásquez-Ibarra, L.: Comparing Two CF+DEA Methods for Assessing Eco-Efficiency from Theoretical and Practical Points of View. Science of the Total Environment 659, 1266–1282 (2019)
14. Ullah, A., Perret, S.R., Gheewala, S.H., Soni, P.: Eco-Efficiency of Cotton-Cropping Systems in Pakistan: An Integrated Approach of Life Cycle Assessment and Data Envelopment Analysis. Journal of Cleaner Production 134(Part B), 623–632 (2016)
15. Carvajal, C.L.Y., Gil, J.C., Cadena, A.D., Cisneros, J.C., Botto-Tobar, M., Yagual, F.E.V.: Impact of Industrial SMEs in the Environment Conservation: A Systematic Mapping Study. International Journal on Advanced Science, Engineering and Information Technology 10(2), 684–690 (2020)
16. Rebolledo-Leiva, R., Angulo-Meza, L., Iriarte, A., González-Araya, M.C.: Joint Carbon Footprint Assessment and Data Envelopment Analysis for the Reduction of Greenhouse Gas Emissions in Agriculture Production. Science of the Total Environment 593–594, 36–46 (2017)
17. Wu, J., Pan, Y., Zhou, Z.: Assessing Environmental Performance with Big Data: A DEA Model with Multiple Data Resources. Computers and Industrial Engineering 177 (2023)

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

