EkBis
Jurnal Ekonomi dan Bisnis
Journal of Economics and Business

EkBis: Jurnal Ekonomi dan Bisnis
Vol. 8, No. 2, 2024, 101–116

Article

Examining the Determinants of Ecological Footprint in ASEAN-5 Countries

[1]Nesha Rizky Ashari, [2]Muhammad Budi Utama, [3]Irwan W.

[123] Sunan Kalijaga State Islamic University Yogyakarta, Indonesian
* Corresponding author: nesharizkyashari16@gmail.com

Article Info

Article History
Received : September 13, 2024
Revised : November 27, 2024
Accepted : December 27, 2024
Published : December 28, 2024

Article DOI:
10.14421/EkBis.2024.8.2.2337

Published by:
FEBI UIN Sunan Kalijaga Yogyakarta

ABSTRACT

This study focuses on the ecological footprint as a crucial indicator for assessing the environmental impact of human activities, particularly in the manufacturing sector, household consumption, and agriculture in five ASEAN countries (Indonesia, Malaysia, Singapore, Thailand, and the Philippines). The novelty of this study lies in the empirical analysis of the relationship between the ecological footprint and major sectors in ASEAN countries using panel data for 22 years (2000–2022). This study uses panel data regression with moderating variables to test the interaction between independent variables and the ecological footprint. The findings indicate that the manufacturing sector has a significant effect on the ecological footprint. The manufacturing sector can reduce its ecological footprint by implementing energy efficiency technologies and using environmentally friendly raw materials. Meanwhile, household consumption does not have a direct effect, but under specific circumstances, it can affect the ecological footprint, particularly the consumption of goods or services that excessively utilize natural resources and are not readily recyclable. The agricultural sector tends to increase its ecological footprint due to inappropriate practices, such as forest burning for agricultural expansion. The conversion of natural land to agricultural land also increases the levels of hazardous substances such as nitrogen and phosphorus in the soil, which have a significant impact on the ecosystem. The findings of this study provide new insights into effective governance strategies to support sustainable development. This study demonstrates that governance plays a major role in managing ecological footprints, emphasizing the significance of government intervention. The implication of this study is the need for policies that support environmentally friendly practices to reduce ecological footprints in the ASEAN-5 countries.

Keywords: Ecological Footprint, Manufacturing, Household Consumption, Agriculture, Institutional.

How to cite: Ashari et al. (2024). Examining the Determinants of Ecological Footprint in ASEAN-5 Countries. *EkBis: Jurnal Ekonomi dan Bisnis, 8*(2), pp. 101-116. DOI: https://doi.org/10.14421/EkBis.2024.8.2.2337

INTRODUCTION

The world faces the challenge of addressing interconnected economic issues such as development and environmental conservation. Environmental conservation has emerged as a

major concern due to its critical nature as a contemporary issue in both developed and developing countries (Dogan et al., 2019). In the modern era, environmental issues have become increasingly urgent, with the ecological footprint serving as a crucial factor in measuring the impact of human activities on the earth. Recently, the ecological footprint has garnered significant attention as a key factor in the implementation of policies related to global warming and climate change (Makhdum et al., 2022). It serves as an aggregate indicator that measures environmental degradation caused by human activities (Ulucak & Lin, 2017).

The ecological footprint has been a central topic in ecological debates among environmentalists (Athira & Subha, 2013). Specifically, concerns have been raised regarding socio-economic metabolism, which has the potential to consume resources and generate waste at unsustainable levels worldwide. According to the Global Footprint Network (2020), the ecological footprint measures human demand for natural resources (Khan et al., 2021). As proposed by Rees (1992), the ecological footprint is widely used as a proxy to determine the current level of environmental degradation (Uzar, 2021).

The manufacturing sector plays a pivotal role in the global economy by supplying essential goods and services necessary for daily life. However, manufacturing activities are often associated with intensive resource use and significant waste production. Environmental impacts such as energy consumption, greenhouse gas emissions, and air and water pollution are direct consequences of manufacturing processes, contributing to an increased ecological footprint (J. Liu et al., 2019). Many companies aim to mitigate the environmental externalities associated with manufacturing. Countries with high manufacturing outputs face challenges related to excessive natural resource consumption, population growth, and environmental degradation (C2ES, 2007), emphasizing the sector's direct contribution to climate change. By-products such as waste vapors, liquids, and solids generated during manufacturing processes further contribute to environmental harm through air, water, and soil pollution, exacerbating ecological concerns. Efforts to offset CO2 emissions from non-renewable energy sources underscore the significance of sustainable resource management in manufacturing operations (Yuan et al., 2020).

Household consumption also significantly impacts the ecological footprint. Consumer lifestyles, consumption patterns, and preferences dictate resource consumption and waste generation levels. Domestic energy consumption, food consumption, and waste production directly influence the ecological footprint (Ivanova et al., 2016). Globally, households account for nearly three-quarters of greenhouse gas emissions, primarily through their consumption of food, energy, and water resources (Wackernagel et al., 2002). This underscores the direct and indirect impacts of household lifestyles on environmental quality and climate change. Consequently, adopting environmentally friendly practices and altering consumption patterns at the household level are critical steps toward mitigating negative environmental impacts (Chiobi et al., 2023).

Agricultural activities have a significant environmental impact, serving as the primary global food supplier and contributing significantly to the ecological footprint. Agriculture not only consumes vast amounts of land and air but also relies heavily on chemical inputs such as fertilizers and pesticides, contributing to greenhouse gas emissions and climate change. Key factors influencing agriculture's footprint include land conversion, chemical usage, and greenhouse gas emissions, each exerting direct environmental

impacts that can escalate the ecological footprint if not managed sustainably (I. Khan et al., 2021).

Effective Governance plays a crucial role in mitigating the environmental impacts of economic activities (Makhdum et al., 2022). Through environmental regulations, energy policies, and sustainability initiatives, governments can effectively moderate the relationships between manufacturing, household consumption, agriculture, and their respective ecological footprints (Epo & Nochi Faha, 2020). Addressing issues related to poor governance and institutional quality stemming from resource wealth is critical. Epo & Nochi Faha (2020) examined how institutional quality affects the ecological footprint across 44 African countries.

This study bridges several gaps in the existing literature by integrating the analysis of manufacturing, household consumption, and agriculture sectors into a comprehensive framework to understand their impacts on the ecological footprint. In addition, this study also underscores the crucial role of government in moderating the relationship between these sectors and the ecological footprint, a topic that has received limited attention in previous studies, particularly within the context of developing countries. The novelty of this study lies in its holistic approach, combining three main sectors along with the role of government. The focus of this study on developing countries provides deeper insights into the unique challenges they face in managing environmental impacts. This study contributes to the existing literature on ecological footprint theory by offering practical recommendations for policymakers to sustainably manage relevant sectors. The findings also open up opportunities for further studies on the role of other sectors, such as energy and transportation, in influencing the ecological footprint in developing countries, which will be crucial for identifying effective strategies for sustainable environmental management.

LITERATURE REVIEW

Manufacturing

Manufacturing plays a crucial role in economic growth, but it also significantly contributes to the ecological footprint. The ecological footprint measures the impact of human activities on the environment through natural resource use and waste production. The manufacturing sector is a major energy consumer and a significant contributor to carbon dioxide emissions. Increased manufacturing is often associated with higher energy consumption and greenhouse gas emissions. A study by Liu et al. (2019) demonstrates that manufacturing requires raw materials such as metals, plastics, and chemicals, the extraction and processing of which increase the ecological footprint. Inefficient resource use and the generation of waste further strain ecosystems.

The relationship between manufacturing and the ecological footprint is complex, influenced by factors such as energy use, pollution, technological efficiency, and environmental policy. Kellens et al. (2017) examined the environmental impact of additive manufacturing processes using life cycle inventory data and found that higher levels of manufacturing production can exacerbate environmental problems. Vachon & Klassen (2008) examined the relationship between environmental management and manufacturing performance on environmental sustainability. A study conducted by Khan et al. (2021) found that manufacturing activities significantly contribute to the ecological footprint within the ten largest manufacturing countries. Yuan et al. (2020) explored the impact of manufacturing on green efficiency in 287 Chinese cities and found that the added value of the

manufacturing industry serves as a positive driver for the ecological footprint.

Household Consumption

Household consumption behavior constitutes an integral part of global climate and environmental policy. Household consumption has a strong correlation with the ecological footprint through energy use, food consumption, water use, and waste production. Rees (1992) explains that all human activities, including household consumption, leave a footprint on the environment. The greater the consumption, the greater the ecological footprint. Changes in consumption patterns toward more efficient and environmentally friendly use of resources can reduce negative impacts on the environment. This includes reducing consumption of energy, water, and food with a high ecological footprint, as well as improving waste management (Jackson, 2005). Studies conducted by (Chiobi et al., 2023; Salo et al., 2016; Shahbaz & Haq, 2022) found that household consumption has a positive effect on the ecological footprint, meaning that an increase in one unit of household consumption can increase the ecological footprint.

Agriculture

The key inputs to agricultural production include fertilizer use, agricultural land, and labor. The use of fertilizer in production causes pollution in groundwater through leakage. Agriculture plays a crucial role in environmental stability because it contributes to the quality of the natural environment through advancements and innovations in agricultural products, while also maintaining fields, plants, and trees. Thus, agricultural work is also considered to play a role in reducing environmental burdens (X. Liu et al., 2017). Reliance on agriculture often discourages other forms of mechanical expansion and protects against some of the adverse effects of contamination and depletion of natural resources. In addition, with growing ecological awareness, agricultural landowners have readily adopted environmentally friendly and personally tailored rural systems, offering numerous social and natural benefits (Sheahan & Barrett, 2017).

Cultivated plants and trees contribute to water retention and infiltration into the earth's crust, thereby reducing human labor and energy consumption. However, the absence of effective methods and the inadequate application of technology in agriculture can significantly contribute to the ecological footprint. Inefficient methods can adversely impact product quality and lead to increased time and resource costs (Abdunnur, 2020). A study conducted by Ivanova et al., (2016) examined the relationship between agriculture and the ecological footprint. Gerdessen & Pascucci (2013) and Lawal (2023) adopted a different approach to evaluating the environmental impact of agriculture by examining the relationship between agriculture and the ecological footprint in Africa. Several studies conducted by (Abdunnur, 2020; Salari et al., 2021; Udemba, 2020) found a positive correlation between agriculture and the ecological footprint.

Institutional

According to the Global Footprint Network (2020), approximately eighty percent of the world's population currently resides in ecologically deficient countries, meaning that resource utilization exceeds the ecosystem's capacity for reproduction. Irrelevant policies, corrupt systems, and political violence affecting resource allocation contribute to these ecological deficits. Collective efforts from all countries are essential to achieving sustainable development, as each nation must identify goals requiring concerted effort. Effective and well-functioning sustainable governance structures must be established to accelerate sustainable development efforts, distinguishing

between good and bad governance (Sun et al., 2023).

One of the most influential and increasingly adopted policy frameworks is ecological compensation. These policies, often implemented through legislation, mandate ecological mitigation measures for new development projects (zu Ermgassen et al., 2022). The objective is to prevent and minimize biodiversity loss resulting from new development and offset residual and existing impacts, with the overall goal of achieving no net loss or net gain of biodiversity (Bull et al., 2013).

METHODOLOGY

This study employs a quantitative approach using secondary data sourced from the official website. The type of data used is panel data with a population of countries that are members of the Association of Southeast Asian Nations (ASEAN). A purposive sampling technique was employed with the criteria of the availability of variable data related to the research object. The sample in this study was 5 countries, namely Indonesia, Malaysia, Singapore, Thailand, and the Philippines. The research period is 22 years from 2000-2022. The data used for each variable is as follows:

Table 1. Operational Definition of Variables

Variable	Type of Variable	Proxied by	Source
Ecological Footprint (LEF)	Dependent	Average (EF Production, EF Import, EF Export, EF Consumption)	Footprint Network
Manufacturing (MVA)	Independent	Manufacturing, Value Added (% of GDP)	World Bank
Household Consumption (HC)	Independent	Final Consumption Expenditure Per Capita Growth (annual %)	World Bank
Agriculture (AGRI)	Independent	Agriculture, Forestry, and Finishing, Value Added (% of GDP)	World Bank
Institutional (INS)	Moderation	Average (CC, GE, PV, RQ, RL, VA) Estimate	World Bank

Source: Author

Based on the literature review, we propose the following model:

$$LEFit = \alpha + \beta 1MVAt + \beta 2HCt + \beta 3AGRIt + \varepsilon \quad \text{..... (1)}$$

The estimated regression model indicates that the ecological footprint (EF) is affected by manufacturing (MVA), household consumption (HC), and agriculture (AGRI).

This method was first developed by Stanley & Jarrell (1989), the model for MRA testing can be expressed by the following equation:

$$LEFit = \alpha + \beta 1MVAt + \beta 2HCt + \beta 3AGRIt + \beta 4INSt + \varepsilon \quad \text{..... (2)}$$

$$LEFit = \alpha + \beta 1MVAt + \beta 2HCt + \beta 3AGRIt + \beta 4INSt + \beta 5MVA * INSt + \beta 6HC * INSt + \beta 7AGRI * INSt + \varepsilon \quad \text{..... (3)}$$

In this case, when the value of β4 in equation (2) is significant, and the values of β5, β6, and β7 in equation (3) are also significant, the moderating variable can be categorized as a "quasi moderator" (Widarjono, 2018). Conversely, when the value of β4 in equation (2) is not significant while the values of β5, β6, and β7 in equation (3) are significant, then the moderating variable can be categorized as a "pure moderator." Furthermore, when the value of β4 in equation (2) is significant, but the values of β5, β6, and β7 in equation (3) are not significant, then the moderating variable can be categorized as

a "moderator predictor." Lastly, when the value of β4 in equation (2) is not significant, and the values of β5, β6, and β7 in equation (3) are also not significant, then the moderating variable can be categorized as a "moderator homogenizer." Subsequently, to produce accurate data and regression results, classical assumptions were tested, thus the study met the BLUE (Best Linear Unbiased Estimator) criteria. The explanation of classical assumption testing includes normality test, multicollinearity test, heteroscedasticity test, and autocorrelation test.

RESULT AND DISCUSSION

Statistical modal testing in this study commences with descriptive statistical analysis, presenting the mean, median, maximum, minimum, standard deviation, and number of observations. The results of the descriptive analysis are presented in Table 2 below.

Table 2. Output of Descriptive Statistics

	LEF	MVA	HC	AGRI	INS
Mean	18.37456	24.09954	3.040928	8.959936	0.227751
Median	18.39731	23.61696	3.485572	9.612377	-0.166696
Maximum	19.55674	31.95328	12.71318	16.31967	1.976446
Minimum	17.10857	17.47442	-13.05474	0.030136	-1.079374
Std. Dev.	0.597618	3.895568	3.302448	4.977959	0.907662
Observations	110	110	110	110	110

Source: E-views, processed 2024

Next, the selection of the best estimation model was conducted to determine the appropriate panel estimation model between the common effect model, fixed effect model, and random effect model. The fixed effects model was identified as the most suitable model, as presented in Table 3 below.

Table 3. Best Model Testing

Test	Prob.	Evidence
Chow	0.0000	Fixed Effect Model
Hausman	0.0000	Fixed Effect Model
Lagrange Multiplier	0.0000	Random Effect Model

Source: E-views, processed 2024

Based on the results of the Chow test to determine the most suitable model between FEM and REM, a probability of 0.0000 was obtained, meaning that the most suitable model between FEM and REM is the FEM model. Furthermore, the researcher conducted a Hausman test to determine the most suitable model between the FEM and CEM models, the results indicated a probability figure of 0.0000, meaning that the selected model is the FEM model. From the two models, the FEM model was selected as the most suitable model. Thus, in this study, the model used to determine the estimation results is the Fixed Effect Model.

To determine the correlation between the variables used in this study, the researcher conducted a multicollinearity test to ensure that there was no strong correlation between each variable. The results of the multicollinearity test are presented in Table 4. below.

Table 4. Output of Multicollinearity

	LEF	MVA	HC	AGRI	INS
LEF	1.000000	0.090410	0.015222	0.666716	-0.632839
MVA	0.090410	1.000000	0.164740	0.238932	-0.291284
HC	0.015222	0.164740	1.000000	0.056642	-0.016621
AGRI	0.666716	0.238932	0.056642	1.000000	-0.956640
INS	-0.632839	-0.291284	-0.016621	-0.956640	1.000000

Source: E-views, processed 2024

Table 4 indicates that none of the variables examined in this study exhibit a strong correlation. This can be seen from the correlation value between variables, none of which exceeds 0.80 because a correlation coefficient exceeding 0.80 generally indicates a strong correlation between variables. Therefore, the data in this study can be subjected to further testing.

Table 5. Output of Heteroscedasticity (Glejser Test)

Variable	Prob	Evidence
MVA	0.0694	Heteroscedasticity does not occur
HC	0.9172	Heteroscedasticity does not occur
AGRI	0.3545	Heteroscedasticity does not occur
INS	0.3636	Heteroscedasticity does not occur

Source: E-views, processed 2024

To obtain efficient and accurate regression results, the researcher subsequently conducted a heteroscedasticity test using the Glejser Test. The criterion for this test was that the probability value of each independent variable should not have a significant effect (at the 0.05 level) on the absolute value of the residuals. This test was performed to determine if there was an inequality of variance in the residuals. Table 5. presents the results of the Glejser Test, indicating that the data in this study are free from heteroscedasticity.

Table 6. Moderated Regression Analysis (MRA)

Variable	LEF
MVA	-0.045912***
HC	0.001028
AGRI	-0.015466
INS	0.350988***
MVA*INS	-0.024068***
HC*INS	-0.000315
AGRI*INS	0.023769*

Source: E-views, processed 2024

Note: The table above presents the coefficient values for the relationship between each independent variable and the dependent variable. Asterisks (***, **, *) denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5 above presents the regression results before and after the interaction of INS. The MVA variable has a negative effect, and INS has a partially positive effect at the 1% level on LEF. On the other hand, the HC and AGRI variables do not have a partial effect on LEF. The interaction relationship of INS on the relationship of the independent variable to the dependent variable indicates varying results. In the relationship between MVA and AGRI and LEF, INS is categorized as a "Quasi Moderator", meaning that the INS variable in the relationship can be a moderator variable and a predictor variable. Whereas, in the relationship between HC and LEF, INS is categorized as a "Predictor Moderator", meaning that the INS variable is predicted to have an effect as a predictor variable.

Manufacturing on Ecological Footprint

Sustainability in the manufacturing sector plays a crucial role in fostering sustainable development processes across society (Gaussin et al., 2013). Sustainable manufacturing encompasses the production of goods using environmentally friendly materials that do not cause harm to the ecosystem, such as not causing pollution, saving energy and natural resources, and being economically healthy and safe for employees, consumers, and the broader community (Li et al., 2021).

The manufacturing sector has a significant impact on the ecological footprint. As seen in the 5 ASEAN countries, an increase in the manufacturing sector has an impact on decreasing the value of the ecological footprint, meaning that increased production from the manufacturing sector in these 5 countries leads to a decrease in the ecological footprint, a crucial factor in a country's environmental health (Doytch et al., 2024). A study conducted by Rafique et al. (2022) revealed that the impact of manufacturing reduces the ecological footprint. This finding aligns with Destek (2021), that the impact of manufacturing can reduce the ecological footprint. Similarly, Ahmed et al. (2019) yielded identical results.

In general, manufacturing activities can have detrimental environmental impacts. In certain instances, the manufacturing sector has a negative impact on forests through the conversion of forested land into agricultural areas or plantations, and even into industrial sites. These actions contribute to deforestation and environmental pollution within the affected regions (Doytch et al., 2024). Apart from forest land conversion, the selection of packaging materials in the manufacturing sector constitutes a significant factor influencing various logistics activities and environmental performance (Silva & Santos, 2022). Most manufacturing companies prefer to use plastic materials, widely recognized for their numerous advantages over other materials. However, despite these advantages, plastics pose significant environmental challenges throughout their lifecycle. These challenges begin with the reliance on fossil fuels for their production and extend to their end-of-life disposal, where most plastics do not decompose naturally (Silva & Molina-Besch, 2023).

This study examines five ASEAN countries, revealing a unique perspective on the manufacturing sector's impact on the ecological footprint. In these countries, increased manufacturing output does not necessarily lead to a larger ecological footprint. On the contrary, it contributes to its reduction. This outcome is attributed to the implementation of renewable energy, environmentally friendly materials, and sustainable production practices that minimize environmental damage and resource exploitation. However, energy use in the manufacturing sector

remains a critical concern, as excessive reliance on non-renewable energy sources can escalate pollution and environmental degradation. Therefore, it is essential to prioritize policies that promote energy efficiency and the transition to clean energy. Industrial machinery must meet minimum energy efficiency standards, and outdated technologies should be phased out gradually. Support from managers and policymakers is crucial to ensuring manufacturing companies adopt environmentally friendly practices (Bhandari et al., 2022). To further encourage energy conservation, tax incentives should be extended to the construction and transportation industries, motivating them to reduce energy consumption. The government should offer financial and policy support for initiatives such as the development of zero-emission vehicles and the construction of energy-efficient buildings. Additionally, offering low-interest credit lines can attract domestic and foreign investment in energy-saving projects. To achieve global climate and sustainable development goals, governments must enforce energy efficiency regulations and collaborate on initiatives that promote energy-saving practices. Raising awareness and encouraging the adoption of energy-efficient devices are vital steps. Specifically, governments in developing countries within the sample must allocate more resources to research and development, foster innovations, and strengthen partnerships with developed countries to facilitate technological advancements (Javed et al., 2024).

The government has established various environmental regulations. However, ineffective implementation and supervision can lead to companies' non-compliance, resulting in a larger ecological footprint from the manufacturing sector. Many companies have not fully integrated ethical values and risk management into their strategies. This can lead to business decisions that disregard environmental impacts, thereby increasing the ecological footprint. In addition, the lack of resources and support to develop an adequate internal control system can hinder companies from ensuring transparency and accountability, which ultimately impacts environmental impact management (Hermawan et al., 2024; Mehmood et al., 2022). To overcome these challenges, collaborative efforts are needed between the government, private sector, and society to improve good governance, strengthen regulation and supervision, and integrate ethical and sustainability values into corporate strategy (Javed et al., 2024).

Household Consumption on Ecological Footprint

In the sample of 5 ASEAN countries in this study, household consumption does not have a direct effect on the ecological footprint. However, under certain conditions, household consumption can have a significant impact on changes in the ecological footprint, such as the consumption of goods or services that use excessive natural resources and cannot be recycled. Abd' Razack et al. (2021) found that household consumption must be adjusted to reduce the ecological footprint through sustainable development. M. S. Khan & Uddin (2018) found that household consumption in the ward exceeded its ecological carrying capacity, meaning that the effect of household consumption indirectly contributed to increasing the ecological footprint. This finding also plays a crucial role in policy formulation, ensuring the implementation of environmentally just practices at the local level. Castellani et al. (2021) in their estimation found that household consumption has an indirect effect on the ecological footprint.

Household consumption can negatively impact the environment through the increased production and use of non-decomposable or non-recyclable plastics. Single-use plastics, including bags, bottles, straws, and cutlery, while

convenient, significantly contribute to environmental pollution. Beyond lifestyle characteristics and habits, the use of single-use items adversely affects the environment. While there is a notable preference for unhealthy and environmentally harmful consumption, a shift towards healthier and more eco-friendly choices is possible if the prices of such products increase significantly and if affordable, healthier alternatives become available. Larger family units residing in separate sub-neighborhoods may encounter greater challenges in adopting healthier and environmentally friendly behaviors compared to nuclear families and individuals. More environmentally friendly patterns are often associated with improved social and economic conditions (Ashery, 2022; Genta et al., 2022).

Energy consumption constitutes another significant household factor impacting the environment. Energy efficiency in households, such as in buildings, electrical equipment, and vehicle fuel usage is crucial (Bohdanowicz et al., 2021). However, saving electrical energy and installing renewable energy equipment in homes is not solely driven by ecological concerns. Individuals may fail to reduce their carbon footprint if they reallocate savings from decreased electricity consumption towards other goods or if they increase energy efficiency without reducing overall consumption. Increasing the popularity of energy-saving solutions while maintaining the established consumption growth trajectory may be insufficient to address environmental threats and the potential reduction of affordable fossil fuels (Bohdanowicz et al., 2021; Moriarty & Honnery, 2021; Tverberg, 2012).

Agriculture on Ecological Footprint

In some cases, the situation is even worse as daily farming activities are focused solely on subsistence. Agriculture has been identified as a major contributor to environmental degradation due to inappropriate practices employed by impoverished communities. These practices include deforestation through burning and cutting, inadequate irrigation, poor sanitation leading to water pollution and endangering aquatic life, and the indiscriminate use of manure and chemicals (Olanipekun et al., 2019; Udemba, 2020).

In a sample of 5 ASEAN countries in this study, it was found that agriculture affects the ecological footprint. This study corroborates the findings of Muoneke et al. (2022); Jiang et al. (2020) comprehensively considered carbon emissions and carbon sequestration to analyze the ecological footprint and agriculture, and the findings indicated that agricultural emissions increased by 41%. Agricultural carbon sequestration indicates an increasing trend with a growth rate of 45%. Boluk & Karaman (2024), in their study, found that environmental damage worsens with economic growth and improves with higher GDP levels. In addition, increasing agricultural added value and energy use can increase the ecological footprint. In other words, agricultural production and energy use are crucial drivers of environmental quality. Therefore, the government must consider policies that lead to sustainable economic growth.

Forest burning for agricultural expansion significantly increases CO2 emissions. While photosynthesis absorbs carbon dioxide from the atmosphere and converts it into organic compounds, plants also release carbon dioxide back into the atmosphere during respiration. The balance between these processes determines whether a forest acts as a carbon sink or a carbon source. When large plants die, soil microorganisms decompose the dead plant material, releasing accumulated CO2 into the environment. Global deforestation is a major source of carbon dioxide emissions, accounting for 6–17% of total emissions, which equates to approximately 5.8

billion tons of CO2 annually (Usman & Makhdum, 2021).

Additionally, the conversion of natural areas to agricultural land increases the levels of harmful substances such as nitrogen and phosphorus in the soil, significantly impacting ecosystems. Excessive water consumption, driven by increased agricultural production, places an additional burden on water resources. Climate change and the rapid increase in water usage are also affecting water resources and leading to a decline in agricultural productivity (Aktürk & Gültekin, 2024).

Government governance plays a crucial role in reducing the ecological footprint. A study indicates that governance in five ASEAN countries has worsened the ecological footprint, underscoring the need for government intervention. Reducing the ecological footprint and managing ecosystems remain critical challenges for sustainable development. Loss of biodiversity also threatens food security, making it imperative to transform food production practices. Countries heavily reliant on agriculture must adopt environmentally friendly practices to ensure sustainable agricultural policies. The growing population, driven by migration and natural birth rates, will increase consumption and, consequently, the ecological footprint. To mitigate this, effective and rapid education, stricter penalties for environmental crimes, and enhanced inspections are essential. Although environmental protection regulations exist in every country, their implementation and monitoring are often inadequate. The core issue lies not in the absence of regulations, but rather in the inadequate enforcement and regular monitoring of existing ones. Therefore, stringent inspections must be conducted to ensure that all sectors involved in food production comply with existing laws (Aktürk & Gültekin, 2024).

CONCLUSION AND RECOMMENDATION

The findings of this study indicate that the manufacturing sector has a significant effect on the ecological footprint. In the ASEAN countries examined, the manufacturing sector can reduce its ecological footprint by implementing energy efficiency technologies and using eco-friendly raw materials. This is achieved through the use of renewable energy, environmentally friendly materials, and sustainable production practices that minimize environmental damage and resource exploitation. However, energy use in the manufacturing sector must be considered, particularly if it remains reliant on renewable energy sources.

Household consumption does not have a direct effect on the ecological footprint in this sample of ASEAN countries. However, under specific circumstances, household consumption has a significant effect on changes in the ecological footprint, particularly the consumption of goods or services that necessitate excessive natural resource utilization and lack of reusability.

The agricultural sector tends to increase its ecological footprint due to inappropriate practices such as burning forests for agricultural expansion. The conversion of natural land to agricultural use also increases the levels of hazardous substances such as nitrogen and phosphorus in the soil, which have a significant impact on the ecosystem. Inadequate air management and the uncontrolled use of chemicals also exacerbate the situation.

The role of the government is crucial in reducing the ecological footprint. This study, examining governance in five ASEAN countries, underscores the critical significance of government intervention in ecological footprint reduction. The transformation of food production practices and the adoption of environmentally friendly agricultural practices are essential to ensuring sustainable agricultural policies.

Practically, the findings suggest a need for more supportive policies to enhance sustainability in the manufacturing, consumption, and agriculture sectors, as well as the need for improved governance to reduce the ecological footprint. Regulators should strengthen sustainable land management and agriculture practices and promote responsible consumption awareness and policies among the public. This study has limitations, such as limited coverage in five countries, and it is recommended to expand the study by incorporating socio-cultural variables and collecting primary data.

REFERENCES

Abd'Razack, N. T. A., Medayese, S. O., & Martins. (2021). Comparative Analysis of Ecological Footprint of Urban and Rural Households in Minna Emirate of Niger State, Nigeria. Journal of Inclusive Cities and Built Environment, 1(2), 41–54. https://doi.org/10.54030/2788-564x/2021/v1i2a5

Abdunnur. (2020). Nexus of fisheries and agriculture production and urbanization on ecological footprint: New evidence from Indonesian economy. International Journal of Energy Economics and Policy, 10(3), 190–195. https://doi.org/10.32479/ijeep.9172

Ahmed, Z., Wang, Z., Mahmood, F., Hafeez, M., & Ali, N. (2019). Does globalization increase the ecological footprint? Empirical evidence from Malaysia. Environmental Science and Pollution Research, 26(18), 18565–18582. https://doi.org/10.1007/s11356-019-05224-9

Aktürk, E., & Gültekin, S. (2024). The impact of food production on ecological footprint in Turkey: an analysis across agriculture, livestock, and aquaculture. Environment, Development and Sustainability, 0123456789. https://doi.org/10.1007/s10668-024-04944-4

Ashery, S. F. (2022). Group Consumption and Ecological Footprint: The Effect of Habits and Lifestyle. Sustainability (Switzerland), 14(20). https://doi.org/10.3390/su142013270

Athira, R., & Subha, V. (2013). Recent Advances in Structural Engineering. American Journal of Engineering Research, 12–19. www.ajer.org

Bhandari, K. R., Ranta, M., & Salo, J. (2022). The resource-based view, stakeholder capitalism, ESG, and sustainable competitive advantage: The firm's embeddedness into ecology, society, and governance. Business Strategy and the Environment, 31(4), 1525–1537. https://doi.org/10.1002/bse.2967

Bohdanowicz, Z., Łopaciuk-Gonczaryk, B., Kowalski, J., & Biele, C. (2021). Households' electrical energy conservation and management: An ecological breakthrough, or the same old consumption-growth path? Energies, 14(20). https://doi.org/10.3390/en14206829

Boluk, G., & Karaman, S. (2024). The impact of agriculture, energy consumption and economic growth on ecological footprint: testing the agriculture-induced EKC for Türkiye. Environment, Development and Sustainability, 26(12), 31817–31837. https://doi.org/10.1007/s10668-024-04672-9

Bull, J. W., Suttle, K. B., Gordon, A., Singh, N. J., & Milner-Gulland, E. J. (2013). Biodiversity offsets in theory and practice. Oryx, 47(3), 369–380. https://doi.org/10.1017/S003060531200172X

C2ES. (2007). A Climate of Change: Manufacturing Must Rise to the Risks and Opportunities of Climate Change. https://www.c2es.org/document/a-climate-of-change-manufacturing-must-rise-to-the-risks-and-opportunities-of-climate-change/

Castellani, V., Sanyé-Mengual, E., & Sala, S. (2021). Environmental impacts of household goods in Europe: a process-based life cycle assessment model to assess consumption footprint. International Journal of Life Cycle Assessment, 26(10), 2040–2055. https://doi.org/10.1007/s11367-021-01987-x

Chiobi, C. J., Joseph, R. T., Chiobi, A., & Omeje, A. N. (2023). Impact of Household Consumption on Ecological Footprint in Nigeria. 18(10), 87–116. https://doi.org/10.5110/77.

Destek, M. A. (2021). Deindustrialization, reindustrialization and environmental degradation: Evidence from ecological footprint of Turkey. Journal of Cleaner Production, 296, 126612. https://doi.org/10.1016/j.jclepro.2021.126612

Dogan, E., Taspinar, N., & Gokmenoglu, K. K. (2019). Determinants of ecological footprint in MINT countries. Energy and Environment, 30(6), 1065–1086. https://doi.org/10.1177/0958305X19834279

Doytch, N., Ashraf, A., & Nguyen, C. P. (2024). Foreign Direct Investment and Forest Land: A Sectoral Investigation. Environmental and Sustainability Indicators, 22(October 2023), 100353. https://doi.org/10.1016/j.indic.2024.100353

Epo, B. N., & Nochi Faha, D. R. (2020). Natural Resources, Institutional Quality, and Economic Growth: an African Tale. European Journal of Development Research, 32(1), 99–128. https://doi.org/10.1057/s41287-019-00222-6

Gaussin, M., Hu, G., Abolghasem, S., Basu, S., Shankar, M. R., & Bidanda, B. (2013). Assessing the environmental footprint of manufactured products: A survey of current literature. International Journal of Production Economics, 146(2), 515–523. https://doi.org/10.1016/j.ijpe.2011.12.002

Genta, C., Sanyé-Mengual, E., Sala, S., & Lombardi, P. (2022). The Consumption Footprint as possible indicator for environmental impact evaluation at city level. The case study of Turin (Italy). Sustainable Cities and Society, 79(August 2021). https://doi.org/10.1016/j.scs.2022.103679

Gerdessen, J. C., & Pascucci, S. (2013). Data envelopment analysis of sustainability indicators of european agricultural systems at regional level. Agricultural Systems, 118, 78–90. https://doi.org/10.1016/j.agsy.2013.03.004

GFN. (2020). Global Footprint Network, Advancing the Science of Sustainability.

Hermawan, A. N., Masudin, I., Zulfikarijah, F., Restuputri, D. P., & Shariff, S. S. R. (2024). The effect of sustainable manufacturing on environmental performance through government regulation and eco-innovation. International Journal of Industrial Engineering and Operations Management, 6(4), 299–325. https://doi.org/10.1108/ijieom-04-2023-0039

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2016). Environmental Impact Assessment of Household Consumption. Journal of Industrial Ecology, 20(3), 526–536. https://doi.org/10.1111/jiec.12371

Jackson, T. (2005). Motivating Sustainable Consumption. A Review of Evidence on Consumer Behaviour and Behavioural Change In A Report to the Sustainable Development Research Network as Part of the ESRC Sustainable Technologies Programme Centre for Environmental Strategy University of Surrey Guildford, 15(January), 1027–1051. https://doi.org/10.1260/0958305043026573

Javed, A., Subhani, B. H., Javed, A., & Rapposelli, A. (2024). Accessing the efficacy of green growth, energy efficiency, and green innovation for environmental performance in top manufacturing nations in the

framework of sustainable development. In Quality and Quantity (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s11135-024-01918-6

Jiang, Q., Matsuzaki, Y., Li, K., & Uitto, J. (2022). Transcriptional regulation and characterization of the promoter region of the human ABCC6 gene. Journal of Investigative Dermatology, 126(2), 325–335. https://doi.org/10.1038/sj.jid.5700065

Kellens, K., Mertens, R., Paraskevas, D., Dewulf, W., & Duflou, J. R. (2017). Environmental Impact of Additive Manufacturing Processes: Does AM Contribute to a More Sustainable Way of Part Manufacturing? Procedia CIRP, 61(Section 3), 582–587. https://doi.org/10.1016/j.procir.2016.11.153

Khan, I., Hou, F., Le, H. P., & Ali, S. A. (2021). Do natural resources, urbanization, and value-adding manufacturing affect environmental quality? Evidence from the top ten manufacturing countries. Resources Policy, 72(February), 102109. https://doi.org/10.1016/j.resourpol.2021.102109

Khan, M. S., & Uddin, M. S. (2018). Household Level Consumption and Ecological Stress in an Urban Area. Urban Science, 2(3), 56. https://doi.org/10.3390/urbansci2030056

Lawal, A. I. (2023). The Nexus between Economic Growth, Energy Consumption, Agricultural Output, and CO2 in Africa: Evidence from Frequency Domain Estimates. Energies, 16(3). https://doi.org/10.3390/en16031239

Li, J., Yuan, Y., & Luo, S. (2021). Raw Material Consumption Controls on Environment Impacts of Sofa Production: A Case Study Based on Ecological Footprint. Wuhan University Journal of Natural Sciences, 26(6), 527–534. https://doi.org/10.1051/wujns/2021266527

Liu, J., Yang, Q., Zhang, Y., Sun, W., & Xu, Y. (2019). Analysis of CO2 emissions in China's manufacturing industry based on extended logarithmic mean division index decomposition. Sustainability (Switzerland), 11(1). https://doi.org/10.3390/su11010226

Liu, X., Zhang, S., & Bae, J. (2017). The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production, 164, 1239–1247. https://doi.org/10.1016/j.jclepro.2017.07.086

Makhdum, M. S. A., Usman, M., Kousar, R., Cifuentes-Faura, J., Radulescu, M., & Balsalobre-Lorente, D. (2022). How Do Institutional Quality, Natural Resources, Renewable Energy, and Financial Development Reduce Ecological Footprint without Hindering Economic Growth Trajectory? Evidence from China. Sustainability (Switzerland), 14(21). https://doi.org/10.3390/su142113910

Mehmood, U., Agyekum, E. B., Kotb, H., Milyani, A. H., Azhari, A. A., Tariq, S., Haq, Z. ul, Ullah, A., Raza, K., & Velkin, V. I. (2022). Exploring the Role of Communication Technologies, Governance, and Renewable Energy for Ecological Footprints in G11 Countries: Implications for Sustainable Development. Sustainability (Switzerland), 14(19), 1–13. https://doi.org/10.3390/su141912555

Moriarty, P., & Honnery, D. (2021). The risk of catastrophic climate change: Future energy implications. Futures, 128, 102728. https://doi.org/https://doi.org/10.1016/j.futures.2021.102728

Muoneke, O. B., Okere, K. I., & Nwaeze, C. N. (2022). Agriculture, globalization, and ecological footprint: the role of agriculture beyond the tipping point in the Philippines. Environmental Science and Pollution Research, 29(36), 54652–54676. https://doi.org/10.1007/s11356-022-19720-y

Olanipekun, I. O., Olasehinde-Williams, G. O., & Alao, R. O. (2019). Agriculture and environmental degradation in Africa: The role of income. Science of The Total Environment, 692, 60–67. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.07.129

Rafique, M. Z., Nadeem, A. M., Xia, W., Ikram, M., Shoaib, H. M., & Shahzad, U. (2022). Does economic complexity matter for environmental sustainability? Using ecological footprint as an indicator. Environment, Development and Sustainability, 24(4), 4623–4640. https://doi.org/10.1007/s10668-021-01625-4

Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: What urban economics leaves out. Environment & Urbanization, 4(2), 121–130. https://doi.org/10.1177/095624789200400212

Salari, T. E., Roumiani, A., & Kazemzadeh, E. (2021). Globalization, renewable energy consumption, and agricultural production impacts on ecological footprint in emerging countries: using quantile regression approach. Environmental Science and Pollution Research, 28(36), 49627–49641. https://doi.org/10.1007/s11356-021-14204-x

Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., & Uotinen, M. (2016). Tailored advice and services to enhance sustainable household consumption in Finland. Journal of Cleaner Production, 121, 200–207. https://doi.org/10.1016/j.jclepro.2016.01.092

Shahbaz, P., & Haq, S. ul. (2022). Food-Energy-and-Water-Nexus-at-Household-Level-Do-Sustainable-Household-Consumption-Practices-Promote-Cleaner-EnvironmentInternational-Journal-of-Environmental-Research-and-Public-Health.pdf.

Sheahan, M., & Barrett, C. B. (2017). Ten striking facts about agricultural input use in Sub-Saharan Africa. Food Policy, 67, 12–25. https://doi.org/10.1016/j.foodpol.2016.09.010

Silva, N., & Molina-Besch, K. (2023). Replacing plastic with corrugated cardboard: A carbon footprint analysis of disposable packaging in a B2B global supply chain—A case study. Resources, Conservation and Recycling, 191(November 2022), 106871. https://doi.org/10.1016/j.resconrec.2023.106871

Silva, N. S. M., & Santos, E. M. (2022). Internationalization in English language courses within Languages without Borders. Letras, 333–353. https://doi.org/10.5902/2176148543163

Stanley, T. D., & Jarrell, S. B. (1989). Meta-Regression Analysis: A Quantitative Method of Literature Surveys. Journal of Economic Surveys, 3(2), 161–170. https://doi.org/https://doi.org/10.1111/j.1467-6419.1989.tb00064.x

Sun, Y., Gao, P., Raza, S. A., & Khan, K. A. (2023). The nonparametric causal effect of sustainable governance structure on energy efficiency and ecological footprint: A pathway to sustainable development. Gondwana Research, 121, 383–403. https://doi.org/https://doi.org/10.1016/j.gr.2023.05.007

Tverberg, G. E. (2012). Oil supply limits and the continuing financial crisis. Energy, 37(1), 27–34. https://doi.org/https://doi.org/10.1016/j.energy.2011.05.049

Udemba, E. N. (2020). Mediation of foreign direct investment and agriculture towards ecological footprint: a shift from single perspective to a more inclusive perspective for India. Environmental Science and Pollution Research, 27(21), 26817–26834. https://doi.org/10.1007/s11356-020-09024-4

Ulucak, R., & Lin, D. (2017). Persistence of policy shocks to Ecological Footprint of the USA. Ecological Indicators, 80(May), 337–343. https://doi.org/10.1016/j.ecolind.2017.05.020

Usman, M., & Makhdum, M. S. A. (2021). What abates ecological footprint in BRICS-T region? Exploring the influence of renewable energy, non-renewable energy, agriculture, forest area and financial development. Renewable Energy, 179, 12–28. https://doi.org/https://doi.org/10.1016/j.renene.2021.07.014

Uzar, U. (2021). The relationship between institutional quality and ecological footprint: Is there a connection? Natural Resources Forum, 45(4), 380–396. https://doi.org/10.1111/1477-8947.12235

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. International Journal of Production Economics, 111(2), 299–315. https://doi.org/10.1016/j.ijpe.2006.11.030

Wackernagel, M., Schulz, N. B., Deumling, D., Linares, A. C., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., & Randers, J. (2002). Tracking the ecological overshoot of the human economy. Proceedings of the National Academy of Sciences of the United States of America, 99(14), 9266–9271. https://doi.org/10.1073/pnas.142033699

Widarjono, A. (2018). Ekonometrika: Pengantar dan Aplikasinya Disertai Panduan EViews (5th ed.). UPPM STIM YKPN.

Yuan, H., Feng, Y., Lee, C. C., & Cen, Y. (2020). How does manufacturing agglomeration affect green economic efficiency? Energy Economics, 92(2020), 104944. https://doi.org/10.1016/j.eneco.2020.104944

Zu Ermgassen, S. O. S. E., Drewniok, M. P., Bull, J. W., Corlet Walker, C. M., Mancini, M., Ryan-Collins, J., & Cabrera Serrenho, A. (2022). A home for all within planetary boundaries: Pathways for meeting England's housing needs without transgressing national climate and biodiversity goals. Ecological Economics, 201, 107562. https://doi.org/https://doi.org/10.1016/j.ecolecon.2022.107562.