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EVALUATION OF INDONESIA'S READINESS FOR EARTH OVERSHOOT DAY 2045 THROUGH ECOLOGICAL FOOTPRINT, BIOCAPACITY, AND RESOURCE CONSUMPTION PROJECTION ANALYSIS

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ABSTRACT

Rapid population growth, increasing resource consumption, and the implementation of the Indonesia Gold 2045 vision are expected to intensify pressure on natural resources, making the assessment of Indonesia's ecological readiness increasingly important. This study evaluates Indonesia's readiness to face Earth Overshoot Day 2045 by integrating Ecological Footprint (EF), biocapacity (BC), ecological deficit, and Earth Overshoot Day (EOD) projections within the Indonesia Gold 2045 framework. A quantitative descriptive approach was employed using historical data from the National Footprint and Biocapacity Accounts (NFBA) for the period 2005-2024. Trend analysis and historical linear trend extrapolation were applied to project future ecological conditions under a Business-as-Usual (BAU) scenario, assuming that current patterns of resource consumption and environmental management continue without significant policy intervention. The results indicate that Indonesia's Ecological Footprint increased from 1.12 to 1.56 gha per capita, while biocapacity declined from 1.48 to 1.20 gha per capita, shifting the country from an ecological reserve to an ecological deficit since approximately 2015. Under the BAU scenario, the Ecological Footprint is projected to reach 2.18 gha per capita, whereas biocapacity is projected to decline to 0.90 gha per capita by 2045, resulting in an earlier occurrence of Earth Overshoot Day and a widening ecological deficit. These findings demonstrate the value of integrating Ecological Footprint, biocapacity, ecological deficit, and Earth Overshoot Day into a single analytical framework for assessing long-term ecological sustainability. The projected trends further indicate that strengthening resource efficiency, accelerating the transition to renewable energy, restoring ecosystems, and promoting circular economy practices will be essential to reduce ecological pressure and support Indonesia's sustainable development toward 2045.

Keywords : Ecological footprint, Biocapacity, Ecological deficit, Earth Overshoot Day, Sustainability

ABSTRAK

Pertumbuhan penduduk yang pesat, meningkatnya konsumsi sumber daya, serta implementasi visi Indonesia Emas 2045 diperkirakan akan meningkatkan tekanan terhadap sumber daya alam, sehingga evaluasi terhadap kesiapan ekologis Indonesia menjadi semakin penting. Penelitian ini bertujuan mengevaluasi kesiapan Indonesia dalam menghadapi Earth Overshoot Day 2045

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melalui integrasi analisis Ecological Footprint (EF), biokapasitas (BC), defisit ekologis, dan proyeksi Earth Overshoot Day (EOD) dalam kerangka Indonesia Emas 2045. Penelitian menggunakan pendekatan deskriptif kuantitatif dengan memanfaatkan data historis National Footprint and Biocapacity Accounts (NFBA) periode 2005–2024. Analisis tren dan ekstrapolasi tren linear historis digunakan untuk memproyeksikan kondisi ekologis hingga tahun 2045 berdasarkan skenario Business-as-Usual (BAU), dengan asumsi bahwa pola pemanfaatan sumber daya dan pengelolaan lingkungan saat ini terus berlanjut tanpa perubahan yang signifikan. Hasil penelitian menunjukkan bahwa Ecological Footprint Indonesia meningkat dari 1,12 menjadi 1,56 gha per kapita, sedangkan biokapasitas menurun dari 1,48 menjadi 1,20 gha per kapita, sehingga Indonesia beralih dari kondisi cadangan ekologis menjadi defisit ekologis sejak sekitar tahun 2015. Dalam skenario BAU, Ecological Footprint diproyeksikan mencapai 2,18 gha per kapita, sedangkan biokapasitas diproyeksikan menurun menjadi 0,90 gha per kapita pada tahun 2045, yang mengakibatkan Earth Overshoot Day terjadi semakin awal dan defisit ekologis semakin melebar. Temuan ini menunjukkan bahwa integrasi analisis Ecological Footprint, biokapasitas, defisit ekologis, dan Earth Overshoot Day memberikan kerangka evaluasi yang lebih komprehensif dalam menilai keberlanjutan ekologis jangka panjang. Tren yang diproyeksikan juga menunjukkan bahwa peningkatan efisiensi sumber daya, percepatan transisi energi terbarukan, restorasi ekosistem, dan penerapan ekonomi sirkular menjadi langkah penting untuk mengurangi tekanan ekologis serta mendukung pembangunan berkelanjutan Indonesia menuju tahun 2045.

Kata kunci : *Jejak ekologis, Biokapasitas, Defisit ekologis, Hari Melampaui Batas, Keberlanjutan*

Introduction

In recent decades, environmental sustainability has become a central focus of the global development agenda as increasing pressure on natural resources arises from economic growth, industrialization, urbanization, and changing consumption patterns. Rising demand for energy, food, and raw materials has accelerated resource exploitation, resulting in major environmental challenges such as climate change, land degradation, biodiversity loss, and ecosystem deterioration. Similar patterns have been observed across developing economies in ASEAN, where increasing household consumption contributes significantly to environmental pressure and resource demand (Ashari et al., 2024). The *Global Resources Outlook* highlights that the continuous increase in natural resource extraction has become one of the primary drivers of global environmental degradation, underscoring the need for development strategies that balance economic progress with the regenerative capacity of natural systems (UNEP, 2024).

One of the most widely used approaches for assessing the sustainability of natural resource utilization is the Ecological Footprint (EF). The Ecological Footprint concept was originally developed by Wackernagel and Rees (1996) as a framework for measuring human demand on ecological systems relative to the Earth's regenerative capacity. This indicator measures the amount of biologically productive land and water required to satisfy human consumption and absorb the resulting waste, particularly carbon emissions. Ecological Footprint analysis is commonly complemented by biocapacity, which represents the ability of ecosystems to generate renewable biological resources and assimilate waste in a sustainable manner. The relationship between these two indicators provides valuable insights into the ecological balance of a region and serves as the basis for determining Earth Overshoot Day, the date on which humanity’s demand for ecological resources

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exceeds the environment's regenerative capacity within a given year (Global Footprint Network, 2025).

Previous studies have demonstrated that ecological pressure is strongly influenced by the interaction among economic growth, energy consumption, and human activities. Expanding production and consumption without corresponding improvements in resource efficiency tends to increase the Ecological Footprint and heighten the risk of ecological deficits. Destek and Sinha (2020) reported that economic expansion and energy consumption remain dominant drivers of ecological pressure in many developing countries. These findings suggest that development performance should not be evaluated solely based on economic indicators but also on a country's ability to maintain a balance between human demands and environmental capacity.

In Indonesia, these challenges are becoming increasingly significant due to rapid population growth and rising demand for energy, food, infrastructure, and land resources. Previous studies in Indonesia found that urbanization has increased energy intensity and environmental pressure through growing demand for transportation, housing, and industrial activities (Irawan & Hartono, 2021). According to data from Statistics Indonesia, the national population has exceeded 280 million and is projected to continue increasing over the coming decades, potentially intensifying pressure on natural resources and the environment (Statistics Indonesia, 2025). Consistent with these trends, the findings of the present study indicate an increasing Ecological Footprint and a declining biocapacity during the observation period, leading to a narrowing ecological balance and an elevated risk of future ecological deficits if effective and sustainable resource management policies are not implemented. These findings underscore the importance of evaluating Indonesia's environmental carrying capacity in anticipation of future development pressures.

Although research on the Ecological Footprint has expanded considerably, most previous studies have focused on the relationships among economic growth, energy consumption, or carbon emissions without integrating biocapacity assessment and long-term projections related to Earth Overshoot Day. Furthermore, studies specifically evaluating Indonesia's preparedness for Earth Overshoot Day in the context of 2045 remain limited. Nathaniel and Khan (2020) emphasized that changes in consumption patterns and rapid urbanization can significantly increase ecological pressure if not accompanied by sustainable development policies. Therefore, there is a clear research gap that warrants a comprehensive approach combining historical analysis with future projections to better understand the dynamics of environmental sustainability in Indonesia.

Unlike previous studies that mainly focused on the relationship between economic growth, energy consumption, and ecological pressure, this study integrates Ecological Footprint analysis, biocapacity dynamics, ecological deficit assessment, and Earth Overshoot Day projections within the Indonesia Gold 2045 framework. This integrated approach provides a more comprehensive evaluation of Indonesia's long-term ecological sustainability and readiness to face future environmental challenges.

Based on these considerations, this study aims to evaluate Indonesia's readiness to face Earth Overshoot Day in 2045 by analyzing trends in the Ecological Footprint,

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changes in biocapacity, and projected resource consumption based on observed patterns. The findings are expected to contribute to the scientific literature on environmental sustainability in Indonesia while providing empirical evidence to support policymaking related to resource-use efficiency, ecosystem conservation, and sustainable development strategies aligned with the vision of Indonesia Gold 2045.

Methods

This study employed a quantitative approach using descriptive and predictive analyses to evaluate Indonesia's readiness to face Earth Overshoot Day in 2045. Annual Ecological Footprint (EF) and biocapacity (BC) data for the period 2005–2024 were obtained from the National Footprint and Biocapacity Accounts published by the Global Footprint Network (2025). These data, expressed in global hectares per capita (gha/capita), were used to examine historical changes in ecological demand and ecosystem capacity.

Descriptive trend analysis was first conducted to identify changes in EF, BC, ecological deficit, and Earth Overshoot Day over the observation period. Future ecological conditions were then projected under a Business-as-Usual (BAU) scenario using linear trend extrapolation. The linear projection was fitted by applying a simple linear regression model, where the observation year served as the independent variable and the annual EF and BC values as the dependent variables. The fitted regression equations were subsequently extrapolated to estimate EF and BC values for 2030, 2035, 2040, and 2045. The projected EF and BC values were then used to estimate the ecological deficit and the timing of Earth Overshoot Day, providing an integrated assessment of Indonesia's ecological readiness toward 2045.

Data Sources and Collection

This study exclusively used secondary data obtained from internationally recognized databases and official publications. Annual data on Ecological Footprint (EF), biocapacity (BC), and related ecological indicators for Indonesia covering the period 2005–2024 were extracted from the 2025 edition of the National Footprint and Biocapacity Accounts, published by the Global Footprint Network (GFN) and accessed through the GFN Open Data Platform in June 2026. Only reported annual values provided by the database were used in this study; no interpolation was performed for the historical dataset. To improve transparency and reproducibility, the complete annual dataset used in this study is provided as Supplementary Table S1.

Supporting demographic and socioeconomic data used to interpret changes in ecological resource consumption were obtained from official publications of Statistics Indonesia (BPS) and the World Development Indicators database (World Bank, 2023). All datasets were checked for completeness and consistency before being organized into an annual time-series format for analysis.

Future Ecological Footprint and biocapacity values were estimated under a Business-as-Usual (BAU) scenario using simple linear regression based on the observed annual data from 2005 to 2024. The regression equations, including the slope, intercept, coefficient of determination (R^2), and projected values, are presented in Appendix A to ensure methodological transparency and facilitate reproducibility.

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The projected EF and BC values were subsequently used to estimate the ecological deficit and Earth Overshoot Day through 2045.

Ecological Footprint and Biocapacity Assessment

The ecological condition of Indonesia was assessed by comparing Ecological Footprint and biocapacity, both expressed in global hectares (gha) or global hectares per capita (gha/capita). Ecological Footprint represents the biologically productive land and water area required to provide the resources consumed by the population and to assimilate generated waste, particularly carbon emissions. In contrast, biocapacity reflects the capacity of ecosystems to regenerate biological resources and absorb waste under prevailing management practices.

The balance between these two indicators was evaluated through the calculation of ecological deficit, which was determined using the following equation:

$$\text{Ecological Deficit} = EF - BC$$

Where:
EF = Ecological Footprint (gha or gha/capita);
BC = Biocapacity (gha or gha/capita).

A positive value indicates an ecological deficit, whereas a negative value indicates an ecological reserve. This assessment framework follows the methodology adopted in the National Footprint and Biocapacity Accounts, which has been widely applied in sustainability assessments and environmental policy studies (Global Footprint Network, 2025).

Resource Consumption Projection and Earth Overshoot Day Estimation

To evaluate Indonesia's ecological readiness toward 2045, future Ecological Footprint (EF) and biocapacity (BC) were projected using a Business-as-Usual (BAU) scenario. The BAU scenario assumes that the long-term historical trajectory of ecological resource use continues in the absence of major technological, institutional, or environmental policy interventions. In this study, the BAU scenario was intended to provide a baseline reference for evaluating future ecological conditions rather than a deterministic prediction.

Future EF and BC values were estimated using simple linear trend extrapolation based on annual observations from 2005 to 2024. The projection model was expressed as:

$$Y_t = a + bt$$

Where (Y_t) is the projected value at year (t), (a) is the intercept, and (b) is the annual rate of change estimated from the historical data. The linear model was selected because it provides a transparent and reproducible baseline approach for long-term ecological assessment and facilitates comparison with future studies employing alternative projection scenarios. Although the historical data indicate a moderate slowdown in EF growth during the most recent observation period, this pattern is not sufficiently consistent to confirm a structural change in the long-term trend. Therefore, the observed slowdown was interpreted as short-term variability

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rather than evidence of a sustained change in ecological dynamics. Consequently, the BAU projection should be interpreted as a reference scenario reflecting the continuation of historical trends under unchanged development conditions.

Earth Overshoot Day (EOD) was estimated using the ratio between biocapacity and Ecological Footprint following the methodology of the Global Footprint Network (2025):

$$\text{EOD} = (\frac{BC}{EF}) \text{ x } 365$$

Where:
BC = Biocapacity;
EF = Ecological Footprint;
365 = number of days in one calendar year.

Lower BC-to-EF ratios indicate greater ecological pressure and result in an earlier occurrence of Earth Overshoot Day. The projected EOD values therefore, represent the estimated timing at which annual ecological demand exceeds the ecosystem's regenerative capacity under the BAU assumption.

Because the projection is based on a single BAU scenario, the results should be interpreted as indicative baseline estimates rather than precise forecasts. Future studies are encouraged to incorporate alternative growth scenarios and uncertainty analyses to evaluate the sensitivity of long-term ecological projections.

Data Analysis

The analytical procedure consisted of four sequential stages: (1) identifying historical trends in Indonesia's Ecological Footprint and biocapacity; (2) quantifying ecological balance through the estimation of ecological deficits; (3) projecting future ecological conditions and resource consumption patterns up to 2045 under the Business-as-Usual scenario; and (4) interpreting the implications of these projections for Indonesia's readiness to face Earth Overshoot Day. The results were presented through tables, graphical visualizations, and narrative interpretation to facilitate comprehensive discussion and to support evidence-based recommendations for sustainable resource management and long-term environmental policy.

Results and Discussion

Trends of Ecological Footprint in Indonesia (2005–2024)

The Ecological Footprint (EF) is a widely used indicator for assessing the pressure of human activities on ecological systems by measuring the biologically productive land and water area required to supply resources and absorb waste generated by consumption. In the context of Indonesia, the trend analysis over the period 2005–2024 indicates a consistent increase in per capita Ecological Footprint. This upward trend reflects growing demand for natural resources driven by population growth, economic expansion, and changes in consumption patterns.

Based on the analysis conducted in this study, Indonesia's Ecological Footprint increased from approximately 1.12 gha/capita in 2005 to 1.56 gha/capita in 2024. This increase indicates that pressure on natural resources has intensified over time,

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particularly in energy, transportation, and household consumption sectors. The Global Footprint Network highlights that carbon demand is the largest component of the global Ecological Footprint, largely driven by continued dependence on fossil fuels (Global Footprint Network, 2025).

Table 1. Trends of Ecological Footprint in Indonesia (2005–2024)

Year	Ecological Footprint (gha/capita)	Change (%)	Interpretation
2005	1.12	–	Relatively low ecological pressure
2010	1.24	+10.7	Increasing energy consumption
2015	1.36	+9.7	Urbanization and industrial growth
2020	1.48	+8.8	Rising household consumption
2024	1.56	+5.4	Increasing ecological pressure

The analysis conducted in this study indicates that Indonesia's Ecological Footprint increased steadily from 1.12 gha/capita in 2005 to 1.56 gha/capita in 2024, reflecting a continuous rise in ecological demand over the past two decades. The increase was primarily associated with greater resource consumption in the energy, transportation, and household sectors, indicating that economic development has been accompanied by increasing pressure on natural resources.

This finding is consistent with the interpretation provided by the Global Footprint Network (2025), the same data source used in this study, which identifies carbon emissions from fossil fuel consumption as the dominant contributor to the Ecological Footprint in most countries. Although this agreement supports the internal consistency of the analysis, it should be recognized that both interpretations are derived from the same ecological accounting database and therefore do not constitute independent empirical verification.

Independent empirical evidence also supports the observed trend. UNEP (2024) reported that increasing material consumption and economic expansion continue to intensify global environmental pressure, particularly in developing economies. Similarly, Destek and Sinha (2020) demonstrated that economic growth and fossil fuel-based energy consumption are positively associated with increases in Ecological Footprint, while Nathaniel and Khan (2020) found that urbanization, income growth, and changes in consumption patterns significantly increase ecological demand through higher energy use, transportation activities, and more resource-intensive lifestyles. These findings are consistent with Indonesia's rapid urbanization and economic transformation over the past two decades.

Although the results of this study indicate that the rate of Ecological Footprint growth moderated slightly during 2020–2024, this pattern should not be interpreted as evidence of a long-term improvement in environmental sustainability. The observed slowdown is more likely to reflect temporary economic adjustments during the post-pandemic recovery period than a structural transition toward sustainable resource use. As emphasized by IPCC (2023), temporary reductions in environmental pressure cannot be considered evidence of sustainable development unless they are supported by sustained changes in energy systems, production processes, and consumption patterns. Therefore, the overall trend identified in this study indicates that Indonesia continues to experience increasing ecological pressure, highlighting the importance of

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accelerating renewable energy deployment, improving resource efficiency, and promoting more sustainable consumption patterns to reduce future ecological risks.

Trends of Biocapacity in Indonesia (2005–2024)

Biocapacity represents the ability of ecosystems to generate renewable biological resources and absorb waste generated by human activities, particularly carbon emissions. It is a key indicator in assessing environmental sustainability because it reflects the regenerative capacity of natural systems. In the context of Indonesia, biocapacity is strongly influenced by the condition of forests, agricultural land, marine ecosystems, and land-use dynamics.

The results of this study indicate that Indonesia's biocapacity per capita experienced a declining trend during the period 2005–2024. The value decreased from approximately 1.48 gha/capita in 2005 to around 1.20 gha/capita in 2024. This decline reflects increasing pressure on land and ecosystem productivity due to deforestation, land conversion, and environmental degradation. Although Indonesia is still considered a country with a relatively high natural resource endowment, the per capita availability of biocapacity continues to decrease as population growth outpaces ecosystem regeneration.

Table 2. Trends of Biocapacity in Indonesia (2005–2024)

Year	Biocapacity (gha/capita)	Change (%)	Interpretation
2005	1.48	–	High ecological availability
2010	1.40	-5.4	Early signs of land pressure
2015	1.32	-5.7	Deforestation and land conversion
2020	1.25	-5.3	Ecosystem degradation continues
2024	1.20	-4.0	Declining regenerative capacity

The decline in biocapacity is closely linked to land-use change, particularly deforestation and the conversion of forest areas into agricultural and plantation land. UNEP (2024) reports that global land-use change remains one of the dominant drivers of biodiversity loss and ecosystem degradation, especially in tropical countries such as Indonesia. Forest ecosystems, which play a major role in carbon sequestration and ecological regeneration, continue to experience fragmentation and reduced productivity.

In addition, increasing population density also contributes to the reduction of biocapacity per capita. As the population grows, the available biologically productive land is distributed among more people, effectively reducing the ecological capacity per individual. According to Global Footprint Network (2025), biocapacity per capita declines not only due to ecosystem degradation but also due to demographic pressure, which reduces the share of productive land per person. Empirical findings by Lin et al. (2018) emphasize that reductions in biocapacity significantly amplify the ecological imbalance when combined with rising Ecological Footprint. This condition leads to widening ecological deficits, where demand for resources exceeds the environment's capacity to regenerate. In the case of Indonesia, this imbalance is increasingly evident over time, indicating a shift toward greater ecological vulnerability.

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Furthermore, environmental stress is also influenced by the expansion of plantation-based economies and infrastructure development. While these activities contribute to economic growth, they often result in reduced ecosystem quality and fragmentation of natural habitats. IPCC (2023) highlights that land-use change remains a critical factor in limiting the capacity of ecosystems to act as carbon sinks, thereby weakening overall biocapacity at national and regional levels.

The declining trend in Indonesia's biocapacity from 2005 to 2024 indicates a gradual reduction in the country's ecological resilience. When combined with the increasing Ecological Footprint, this trend confirms that Indonesia is moving toward a widening ecological deficit condition. Without effective ecosystem restoration, sustainable land management, and conservation policies, the decline in biocapacity is likely to continue and may significantly affect environmental sustainability in the long term.

Ecological Balance and Ecological Deficit

The balance between Ecological Footprint (EF) and biocapacity (BC) represents a fundamental indicator of environmental sustainability. When the Ecological Footprint exceeds biocapacity, the system enters an ecological deficit condition, indicating that the demand for ecological resources surpasses the ecosystem's regenerative capacity. Conversely, when biocapacity exceeds Ecological Footprint, an ecological reserve exists, reflecting a surplus of natural capital. This framework is widely used in sustainability assessments to evaluate whether a country operates within its ecological limits (Global Footprint Network, 2025).

Based on the results of this study, Indonesia has experienced a persistent shift from ecological balance toward ecological deficit over the period 2005–2024. This condition is primarily driven by a continuous increase in Ecological Footprint alongside a gradual decline in biocapacity, as discussed in the previous sections. The widening gap between these two indicators reflects increasing pressure on natural ecosystems and indicates that Indonesia is gradually exceeding its ecological carrying capacity.

Table 3. Ecological Footprint, Biocapacity, and Ecological Deficit in Indonesia (2005–2024)

Year	Ecological Footprint (gha/capita)	Biocapacity (gha/capita)	Ecological Balance (BC − EF)	Status
2005	1.12	1.48	+0.36	Ecological reserve
2010	1.24	1.40	+0.16	Near balance
2015	1.36	1.32	-0.04	Early deficit
2020	1.48	1.25	-0.23	Ecological deficit
2024	1.56	1.20	-0.36	Deepening deficit

The results indicate that Indonesia transitioned from an ecological reserve condition in the early period (2005) to a clear ecological deficit after 2015. The widening negative gap between Ecological Footprint and biocapacity suggests that resource consumption is increasingly dependent on ecological overshoot. This finding is consistent with the Global Footprint Network (2025), which reports that many developing countries are currently operating under ecological deficit conditions due to rising consumption and declining ecosystem productivity.

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The deterioration of ecological balance is closely linked to land-use change, deforestation, and increasing demand for energy and land resources. UNEP (2024) emphasizes that land-use change remains one of the most significant drivers of biocapacity loss, particularly in tropical regions where agricultural expansion and infrastructure development continue to reduce forest cover and ecosystem functionality. Furthermore, Lin et al. (2018) explain that ecological deficit emerges when the rate of Ecological Footprint growth exceeds biocapacity regeneration capacity over time, leading to structural environmental imbalance. In Indonesia's case, the persistent widening gap indicates that ecological recovery capacity is not keeping pace with consumption demand.

The ecological deficit trend also reflects broader socio-economic dynamics, including population growth, urban expansion, and increasing consumption intensity. Nathaniel and Khan (2020) highlight that urbanization significantly amplifies ecological pressure in developing economies through increased energy demand, transportation needs, and lifestyle transitions. These patterns are highly relevant to Indonesia's development trajectory over the past two decades.

The findings confirm that Indonesia has moved from ecological sustainability toward an increasingly severe ecological deficit condition. Without significant intervention in resource efficiency, land restoration, and energy transition, the ecological gap is likely to continue widening, thereby increasing environmental risks and reducing long-term sustainability.

Similar ecological deficit trends have also been reported in rapidly developing economies such as China, India, and several ASEAN countries, where economic growth and urban expansion have increased ecological demand faster than ecosystem regeneration capacity (Global Footprint Network, 2025). This suggests that Indonesia's experience reflects a broader sustainability challenge faced by emerging economies.

Drivers of Increasing Ecological Footprint

The increasing trend of Ecological Footprint (EF) in Indonesia is driven by a combination of socio-economic, demographic, and environmental factors that interact in a complex system. These drivers are primarily associated with economic expansion, population growth, urbanization, and energy consumption patterns. As Indonesia continues to develop, these factors collectively intensify the demand for natural resources and accelerate environmental pressure. To provide a clearer understanding of the interaction among these factors, a conceptual framework was developed to illustrate how economic growth, urbanization, population growth, and land-use change influence ecological pressure through energy consumption, industrial activity, transportation demand, and resource utilization. The framework highlights the pathways through which human activities increase Ecological Footprint and contribute to declining biocapacity.

The historical data analyzed in this study indicate that the simultaneous increase in Ecological Footprint and decline in biocapacity are closely associated with these interacting drivers, suggesting that Indonesia's ecological pressure results from the combined effects of economic growth, demographic change, urban expansion, and land-use transformation rather than from a single dominant factor.

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One of the main drivers is economic growth, which is closely linked to rising consumption of energy and material resources. Expanding industrial activities, transportation systems, and household consumption patterns contribute significantly to higher ecological demand. Destek and Sinha (2020) emphasize that economic growth in developing countries tends to increase ecological pressure when it is heavily dependent on non-renewable energy sources. In Indonesia, this condition is reflected in the dominance of fossil-fuel-based energy in supporting industrial and transportation sectors.

Another important factor is urbanization. Rapid urban development leads to increased demand for infrastructure, housing, electricity, and transportation services. Similar findings were reported by Sadorsky (2014), who demonstrated that urbanization contributes significantly to increasing energy consumption and carbon emissions in emerging economies. Nathaniel & Khan (2020) found that urbanization significantly contributes to rising Ecological Footprint in Indonesia due to higher energy consumption and lifestyle changes associated with urban living. This includes increased private vehicle usage, higher electricity demand, and greater consumption of manufactured goods.

Population growth also plays a significant role in increasing the Ecological Footprint. As the number of inhabitants rises, total demand for food, energy, water, and land resources increases proportionally. According to UNEP (2024), demographic pressure is one of the key factors that intensifies global resource consumption and accelerates environmental degradation, particularly in developing economies with limited ecological regeneration capacity.

In addition, land-use change and deforestation significantly contribute to ecological pressure by reducing ecosystem services and carbon absorption capacity. Expansion of agricultural land, plantations, and infrastructure development often comes at the expense of forest ecosystems, which are critical for maintaining biocapacity. The IPCC (2023) highlights that land-use change remains one of the largest contributors to biodiversity loss and carbon emissions globally. The interaction among these drivers and their pathways toward ecological pressure are summarized in Figure 1.

The conceptual framework illustrates that the Ecological Footprint in Indonesia is influenced by multiple interconnected drivers. Economic growth and urbanization primarily increase energy demand, transportation intensity, and industrial production. Population growth amplifies overall resource consumption, while land-use change reduces ecological regeneration capacity. These drivers do not operate independently; rather, they reinforce one another through feedback mechanisms. For example, economic growth often accelerates urbanization and energy consumption, while land-use change simultaneously reduces the ecological capacity required to absorb increasing environmental pressures.

When these pressures increase simultaneously, the result is a widening gap between Ecological Footprint and biocapacity. This imbalance accelerates ecological degradation and strengthens the likelihood of ecological deficit conditions. UNEP (2024) and IPCC (2023) both emphasize that without structural transformation in energy systems and land management, developing countries will face increasing difficulty in maintaining ecological balance. This conceptual relationship is consistent

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with the empirical findings of the present study, which show a continuous increase in Ecological Footprint from 1.12 gha/capita in 2005 to 1.56 gha/capita in 2024, accompanied by a decline in biocapacity from 1.48 gha/capita to 1.20 gha/capita during the same period.

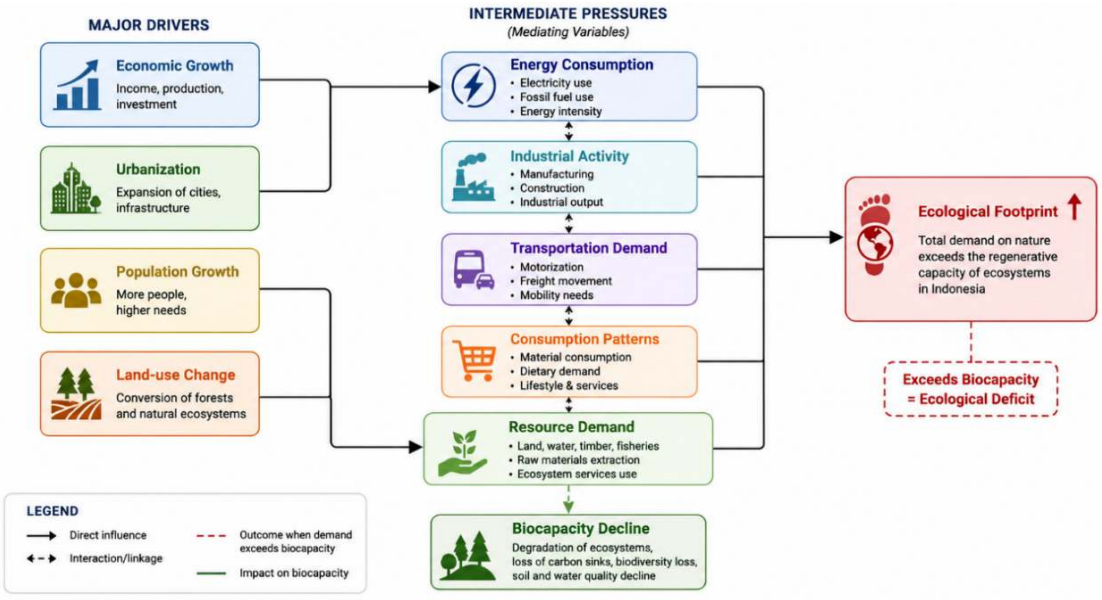

Figure 1. Conceptual Framework of Drivers of Ecological Footprint in Indonesia

Projection of Ecological Footprint and Biocapacity up to 2045

The projection of Ecological Footprint (EF) and biocapacity (BC) is essential to evaluate Indonesia's future ecological condition, particularly in assessing its readiness toward Indonesia's development vision 2045. This study applies a Business-as-Usual (BAU) approach, assuming that historical trends of increasing Ecological Footprint and declining biocapacity continue without significant policy or technological transformation.

The projection results indicate that Ecological Footprint will continue to increase gradually, while biocapacity is expected to decline due to ongoing land-use change, population growth, and environmental degradation. This divergence between demand and ecological supply suggests that Indonesia will face a widening ecological deficit if current development patterns persist. This finding raises important concerns regarding the environmental dimension of Indonesia Gold 2045. While economic growth remains a key development target, achieving long-term prosperity will require balancing economic expansion with ecological sustainability and resource efficiency.

Table 4. Projected Ecological Footprint and Biocapacity of Indonesia (2024-2045)

Year	Ecological Footprint (gha/capita)	Biocapacity (gha/capita)	Ecological Balance (BC − EF)	Status
2024	1.56	1.20	-0.36	Ecological deficit
2030	1.72	1.12	-0.60	Severe deficit
2035	1.86	1.05	-0.81	Deep deficit
2040	2.01	0.98	-1.03	Critical deficit
2045	2.18	0.90	-1.28	Highly unsustainable

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The projection shows that by 2045, Indonesia's Ecological Footprint may reach approximately 2.18 gha/capita, while biocapacity declines to around 0.90 gha/capita. This results in a significant ecological deficit, indicating that the country would require more than twice its available biological capacity to sustain current consumption patterns. These projected values should be interpreted as indicative baseline estimates under the Business-as-Usual assumption rather than deterministic forecasts. The actual ecological trajectory may differ depending on future technological development, policy implementation, demographic dynamics, and changes in resource-use patterns.

This trend aligns with findings from the Global Footprint Network (2025), which explains that countries with rapidly growing populations and expanding economies tend to experience increasing ecological deficits when consumption growth outpaces ecosystem regeneration capacity. Similarly, UNEP (2024) highlights that continued reliance on resource-intensive development pathways will intensify pressure on land, energy, and water systems.

Destek and Sinha (2020) also emphasize that without structural changes in energy systems and production efficiency, economic growth will continue to drive ecological pressure upward. In Indonesia's case, fossil-fuel dependence remains a key factor influencing the rising Ecological Footprint trajectory.

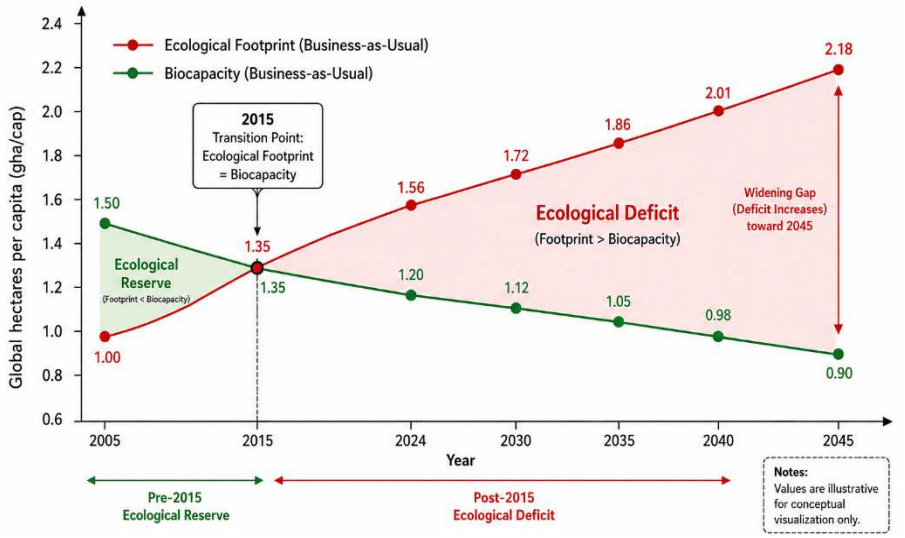

Figure 2. Projection of Ecological Footprint and Biocapacity in Indonesia (2005–2045)

The figure demonstrates a clear divergence between Ecological Footprint and biocapacity over time. While the Ecological Footprint continues to rise due to increasing consumption, biocapacity gradually declines due to ecosystem degradation and land conversion. The widening gap after 2024 indicates that Indonesia is moving further away from ecological balance.

UNEP (2024) notes that such divergence is typical in developing economies undergoing rapid industrialization without sufficient environmental safeguards. Meanwhile, IPCC (2023) emphasizes that land-use change and carbon-intensive development patterns significantly reduce the long-term regenerative capacity of ecosystems.

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Estimation of Earth Overshoot Day in Indonesia

Earth Overshoot Day (EOD) is an indicator that marks the date when humanity's demand for ecological resources within a given year exceeds Earth's capacity to regenerate those resources in the same year. The calculation is based on the ratio between biocapacity and Ecological Footprint, expressed in global hectares (gha). This indicator has been widely used to illustrate ecological overshoot at both global and national scales (Global Footprint Network, 2025).

In the context of Indonesia, the estimation of Earth Overshoot Day is conducted using the relationship between Ecological Footprint (EF) and biocapacity (BC), where a declining BC combined with an increasing EF leads to an earlier overshoot date. The results of this study indicate that Indonesia's ecological system has transitioned from a relatively balanced condition in the early 2000s toward a persistent ecological deficit condition after 2015, which continues to deepen up to the projected year 2045.

The estimation shows that Indonesia's Earth Overshoot Day has shifted progressively earlier over time, reflecting increasing pressure on natural resources. This shift is driven by rising consumption patterns, fossil-fuel dependence, and land-use change, which reduce the ability of ecosystems to regenerate resources at the same pace as demand (UNEP, 2024). The continued widening gap between EF and BC also indicates that Indonesia is consuming ecological resources faster than they can be replenished. It should be noted that the estimated Earth Overshoot Day presented in this study represents an approximation derived from the projected Ecological Footprint and biocapacity under the Business-as-Usual scenario. Consequently, future changes in environmental policy, technological innovation, or resource management may alter the estimated timing of ecological overshoot.

Table 5. Estimated Earth Overshoot Day of Indonesia (2005-2045)

Year	EF (gha/capita)	BC (gha/capita)	BC/EF Ratio	Earth Overshoot Day (Day of Year)	Approx. Date
2005	1.12	1.48	1.32	No Overshoot	–
2010	1.24	1.40	1.13	No Overshoot	–
2015	1.36	1.32	0.97	354	Late December
2020	1.48	1.25	0.84	308	Early November
2024	1.56	1.20	0.77	281	Early October
2030*	1.72	1.12	0.65	238	Late August
2045*	2.18	0.90	0.41	151	Late May

*Projected values (Business-as-Usual scenario)

The results indicate a clear acceleration of ecological overshoot in Indonesia. While Indonesia still maintained an ecological reserve in 2005 and 2010, Earth Overshoot Day began to emerge after 2015 and is projected to occur progressively earlier over time. By 2045, the overshoot date is estimated to fall in late May, indicating a substantial increase in ecological pressure. This trend demonstrates that Indonesia's ecological demand is growing faster than the regenerative capacity of its ecosystems.

By 2024, Earth Overshoot Day is estimated to occur around the 281st day of the year (early October), indicating that Indonesia's ecological demand exceeds its

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annual regenerative capacity before the end of the year. Under the Business-as-Usual scenario, this situation is projected to worsen significantly, with the overshoot date shifting to late May by 2045. Such a shift reflects the increasing imbalance between resource consumption and ecological regeneration capacity.

This trend is consistent with findings from the Global Footprint Network (2025), which reports that countries operating under ecological deficit conditions tend to experience progressively earlier overshoot dates as consumption grows faster than ecosystem regeneration. Similarly, UNEP (2024) emphasizes that unsustainable resource-use patterns, particularly in energy and land systems, accelerate ecological overshoot at both national and global scales.

The movement of Earth Overshoot Day toward earlier dates reflects structural imbalances in Indonesia's development system. IPCC (2023) highlights that continued reliance on fossil-fuel-based energy systems and extensive land-use change significantly reduce ecological resilience, thereby increasing the rate at which ecological limits are exceeded. Without substantial intervention, this trajectory may increase dependence on ecological imports, accelerate natural capital depletion, and pose challenges to achieving environmentally sustainable development by 2045.

Policy Implications and Indonesia's Readiness toward 2045

The increasing gap between Ecological Footprint (EF) and biocapacity (BC), along with the accelerating shift of Earth Overshoot Day, indicates that Indonesia is facing growing ecological pressure that may challenge the sustainability of its long-term development agenda. The projection results toward 2045 suggest that, under a Business-as-Usual scenario, ecological demand will significantly exceed ecological supply, leading to a widening ecological deficit. This condition highlights the need for stronger integration between economic development policies and environmental carrying capacity.

The results of this study show that Indonesia's ecological system is moving toward a condition where resource consumption is increasingly detached from ecosystem regeneration capacity. This trend is consistent with Global Footprint Network (2025), which reports that most countries experiencing rapid economic and demographic growth tend to enter ecological deficit when consumption patterns are not balanced by improvements in resource efficiency. Similarly, UNEP (2024) emphasizes that unsustainable production and consumption systems remain the primary driver of global ecological overshoot, particularly in developing economies.

From a policy perspective, the findings indicate that Indonesia's readiness to face environmental challenges toward 2045 depends on the extent to which structural transformation can be implemented. Without intervention, continued reliance on fossil energy, land conversion, and resource-intensive production systems will further deepen ecological imbalance. York (2012) argues that renewable energy expansion does not automatically displace fossil fuel consumption unless accompanied by structural transformation in the energy system. IPCC (2023) highlights that energy transition and land-use reform are critical pathways for reducing environmental pressure and enhancing long-term ecosystem resilience.

The ecological deficit trend also suggests that current development strategies need to incorporate stronger ecological constraints. Economic growth alone is not

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sufficient to ensure sustainability if it is accompanied by increasing resource intensity. Destek and Sinha (2020) emphasize that decoupling economic growth from environmental degradation requires significant improvements in energy efficiency, technological innovation, and regulatory enforcement.

In the Indonesian context, several strategic pathways can be identified to improve ecological readiness toward 2045. These include accelerating the renewable energy transition, strengthening forest conservation and restoration programs, promoting circular economy practices, and improving resource efficiency in industrial sectors. These strategies are aligned with global sustainability frameworks and are essential to reduce ecological pressure while maintaining economic development goals.

Table 6. Strategic Policy Directions for Improving Ecological Readiness toward 2045

Policy Area	Current Condition	Key Challenge	Recommended Strategy	Expected Impact
Energy System	High fossil fuel dependence	High carbon footprint	Renewable energy transition	Reduction of Ecological Footprint
Land Use	Ongoing deforestation	Declining biocapacity	Forest restoration & protection	Increase biocapacity
Industry	Resource-intensive production	Low efficiency	Eco-efficiency & clean production	Lower resource intensity
Consumption	Rising urban consumption	High waste generation	Circular economy implementation	Waste reduction & reuse
Governance	Sectoral policy approach	Weak integration	Integrated sustainability policy	Systemic ecological balance

Overall, Indonesia's ecological readiness toward 2045 is currently challenged by a persistent imbalance between resource demand and ecological regeneration capacity. If no significant transformation occurs, the ecological deficit is likely to expand further, increasing environmental risks and reducing long-term sustainability. However, with appropriate policy interventions and structural changes, it is still possible to redirect the trajectory toward a more balanced and sustainable ecological condition.

Study Limitations and Research Implications

The findings of this study should be interpreted by considering several methodological limitations. First, the analysis was entirely based on secondary data obtained from the *National Footprint and Biocapacity Accounts* (Global Footprint Network, 2025), which are generated using standardized ecological accounting methods that inherently contain uncertainty and are accompanied by data quality scores reflecting differences in data availability, completeness, and reliability among reporting sources. Second, this study adopts the national ecological accounting framework provided by the Global Footprint Network and therefore does not compare territorial accounting with consumption-based accounting, which may produce different estimates of ecological pressure due to international trade and

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embodied resource flows. Third, the future projections were developed using a Business-as-Usual (BAU) scenario based on a simple linear trend and should therefore be interpreted as a baseline scenario rather than a deterministic forecast, as the results remain sensitive to the assumption of a linear functional form. Finally, this study does not evaluate alternative policy-intervention scenarios or conduct sensitivity analyses. Future research is therefore encouraged to compare multiple projection models and policy scenarios to improve the robustness of long-term ecological projections and support more evidence-based sustainability policymaking toward Indonesia Gold 2045. Despite these limitations, the present study provides a comprehensive baseline assessment of Indonesia's ecological condition by integrating Ecological Footprint, biocapacity, ecological deficit, and Earth Overshoot Day projections within a single analytical framework, thereby offering useful evidence for future sustainability planning and policy evaluation.

Conclusion

Indonesia’s Ecological Footprint shows a consistent upward trend during the period 2005–2024, indicating increasing pressure on natural resources driven by economic expansion, urbanization, and shifting consumption patterns. This trend reflects a growing imbalance between human demand for ecological resources and the capacity of ecosystems to sustain them.

In contrast, biocapacity demonstrates a declining trajectory over the same period, primarily influenced by deforestation, land-use change, and environmental degradation. The simultaneous increase in Ecological Footprint and decline in biocapacity has shifted Indonesia from a condition of ecological reserve to a persistent ecological deficit since around 2015.

The widening gap between Ecological Footprint and biocapacity confirms that resource consumption has exceeded ecological regeneration capacity. This condition has also contributed to the progressive advancement of Earth Overshoot Day, which in 2024 is estimated to occur in early October and is projected to shift further earlier under current consumption patterns.

Projections toward 2045 indicate that, under a Business-as-Usual scenario, Ecological Footprint will continue to increase while biocapacity is likely to decline further. This trajectory will deepen the ecological deficit and intensify environmental pressure, posing significant risks to long-term ecological sustainability.

Unlike previous studies that primarily examined Ecological Footprint or biocapacity separately, this study provides an integrated assessment by combining Ecological Footprint, biocapacity, ecological deficit, and Earth Overshoot Day projections within the Indonesia Gold 2045 framework. This integrated approach offers a more comprehensive basis for evaluating long-term ecological sustainability and supporting strategic environmental planning. Because the present analysis represents a Business-as-Usual baseline scenario, future studies should develop alternative policy-intervention scenarios, conduct sensitivity analyses, and perform sub-national Ecological Footprint and biocapacity assessments to better quantify uncertainty and support evidence-based sustainability policies in Indonesia.

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