

From theory to application: measuring development disparities in Mozambique through an Odum-inspired energy framework

Estêvão Salvador Langa, Biagio F. Giannetti^{*} , Fábio Sevegnani , Feni Agostinho ,
Cecília M.V.B. Almeida 

Post-graduation Program on Production Engineering, Paulista University (UNIP), Brazil

ARTICLE INFO

Keywords:

Development
Disparities
Economic-environmental-social indicator
SADC
5SEnSU model

ABSTRACT

This study proposes an integrative framework for assessing development disparities grounded in Howard T. Odum's systems ecology and energy theory. Drawing upon the Five Sector Sustainability (5SEnSU) model, the framework captures economic, environmental, and social dimensions of performance through a systemic and energetically grounded lens. Using Mozambique and its trade relationships within and beyond the Southern African Development Community (SADC) as a case study, the IDEAS index (Integrated Development Energy Adjusted Score) is introduced. It is based on five normalized indicators: GDP per unit of energy, GDP per capita, GDP per workforce, GDP per CO₂ emissions, and GDP per population below the poverty line. Results for 2014 reveal pronounced structural disparities, with Mozambique exhibiting one of the lowest performances (IDEAS = 0.076) and disparity ratios exceeding 1.2 in comparison to developed countries. By embedding Odum's principles of energy hierarchy, feedback, and self-organization, the proposed framework offers a robust tool for diagnosing systemic imbalances and guiding ecologically informed development strategies. This contribution aims to operationalize Odum's legacy within international sustainability assessments and offers a more coherent alternative to conventional economically centered metrics.

1. Introduction

Achieving sustainable development remains one of the central challenges of the 21st century. It requires finding an effective balance between the use of natural resources, the environmental consequences of economic activity, and the social benefits that result from these processes. Regional disparities are a clear reflection of this challenge: while some areas enjoy resource abundance, others face critical shortages, often leading to higher unemployment rates, limited educational access, reduced market participation, and even population decline (Rice and Venables, 2003; Storper, 2018; Öberg and Aronsson, 2022). Such imbalances typically stem from unequal access to externalities, infrastructure, technology, energy and mineral reserves, and institutional capacity (Karaalp-Orhan, 2020).

Reducing territorial inequalities is a key pillar of the 2030 Agenda and features prominently in national and multilateral development strategies. This topic has attracted considerable academic attention (Fosu, 2009; 2017; Barbier, 2005; 2012; Nel, 2008; 2018), as persistent structural gaps continue to hinder inclusive progress. According to

United Nations Conference on Trade (2018), the world's least developed countries remain heavily marginalized—particularly in Africa, which, despite its resource wealth, continues to exhibit the highest levels of global inequality (ADB, 2015a). In many of these economies, a large share of the population depends directly on natural resource extraction for survival, which constrains their long-term development trajectory (Barbier, 2005).

Nel (2008) defines disparity as the skewed distribution of valued and scarce natural resources, within nations and across borders. Doyle and Stiglitz (2014) posit that absolute equality between nations is not the ultimate objective, as specific economic disparities are essential for the advancement and prosperity of countries. Hence, the configuration of economic relationships between nations emerges as a pivotal factor in shaping disparity, as highlighted by Melamed and Samman (2013). The disparities between nations are molded and perpetuated by the dynamics of the international economic framework and the structures governing these interactions (Melamed and Samman, 2013; Doyle and Stiglitz, 2014). When disparities become too large, they tend to produce adverse outcomes for social well-being, including political instability,

^{*} Corresponding author.

E-mail address: biafgian@unip.br (B.F. Giannetti).

<https://doi.org/10.1016/j.ecolmodel.2025.111287>

Received 2 May 2025; Received in revised form 29 June 2025; Accepted 31 July 2025

Available online 14 August 2025

0304-3800/© 2025 Elsevier B.V. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

restricted social mobility, and stagnant income growth, leading to persistent poverty traps (Nguyen et al., 2019; Chetty et al., 2017; van Bergeijk and van der Hoeven, 2017).

Poverty, a persistent global concern, is further exacerbated by the widening gap between rich and poor nations (Fosu, 2018). A study by Lakner et al. (2022) showed that a 1 % annual reduction in each country's Gini index would yield a more significant decrease in poverty than a comparable increase in economic growth. These findings highlight the importance of equity-focused policies in accelerating poverty alleviation and underscore the relevance of Sustainable Development Goal #10, which seeks to reduce inequality within and among countries (Odusola et al., 2017).

Substantial differences in economic performance and quality of life are reflected in a wide range of indicators, including income per capita, access to education, and health outcomes. These disparities can undermine economic efficiency by trapping regions in cycles of poverty and underutilization of their human and natural capital (Floerkemeier et al., 2021). In response, contemporary development frameworks increasingly call for multidimensional metrics capable of capturing the complex interplay between economic growth, social well-being, and environmental sustainability (Ulman et al., 2021).

Several recent studies have explored these interconnections using integrated approaches. Das and Basu (2022), for example, examined the link between inequality and pollution across 129 countries, showing that environmental protection can support social inclusion. Geng et al. (2022) analyzed the influence of social disparities on environmental sustainability in G10 economies, while Öberg and Aronsson (2022) investigated the ecological impacts of economic inequality. Other frameworks, such as the Inclusive Green Growth Index proposed by Wang et al. (2022) or the work of Pozo et al. (2020) on environmental inequality, emphasize the need to consider sustainability not only as an ecological imperative but also as a matter of distributive justice. Teixidó-Figueras et al. (2016) highlighted higher disparity levels for ecological footprint indicators, while Hao et al. (2016), Islam (2015) and Cheikh et al. (2023) confirmed that local income disparity is negatively correlated with environmental indicators. Although advances are being obtained in assessing disparities among nations, the literature shows that there is a lack of emphasis on the application of conceptual models and approaches capable of quantitatively and in an integrated manner embracing environmental, social, and economic sectors to study disparities.

Schandl et al. (2016) outlined that a scenario analysis offers crucial insights into the environmental, economic, and social repercussions of policy decisions. This analysis is pivotal for shaping the future economic landscape within a resource-efficient global economy. A primary goal is to foster human development while steering toward accomplishing Sustainable Development Goals (SDGs) on a more resilient trajectory. According to the United Nations Environment Programme (UNEP, 2012), countries must evaluate their performance not solely based on conventional measures like the Human Development Index (HDI) or economic growth but also by assessing the proportion of their total resource consumption derived from natural sources.

In response, the integration of the Five Sector Sustainability (5SEnSU; Giannetti et al., 2019) model alongside multi-indicators emerges as a practical approach to meet UNEP's imperative. The 5SEnSU model represents a significant advancement in measuring disparity and sustainability, offering a multidimensional analysis that surpasses previous approaches' limitations. The model enables a more comprehensive and integrated understanding of internal and external disparities, guiding more effective policies and promoting sustainable development. The 5SEnSU takes into account natural, social, and economic capital within an open system. It allocates both donor and receiver roles to natural and social sectors, thus providing an understanding of resource dynamics. It rests upon six axioms rooted in epistemological principles, acknowledging the biophysical limits of the planet in supporting development. Consequently, it is a

multidimensional, multicriteria, and multimetric tool, facilitating holistic assessments.

Based on the 5SEnSU model, this study aims to propose and apply a novel approach to quantify disparities among nations integratively. To demonstrate the applicability of the proposed model for evaluating disparities across nations, Mozambique serves as the reference case, with particular attention given to its trade dynamics within the Southern African Development Community (SADC). As the poorest country in Southern Africa and one of the ten least developed globally (World Bank, 2018; ADB, 2015b; Southern African Development Community, 2020), Mozambique exemplifies structural challenges faced by low-income economies. By incorporating multiple dimensions beyond conventional GDP measures, which often obscure deeper inequalities, this study offers a more comprehensive approach to quantifying international disparity.

Given the growing relevance of integrated frameworks for sustainability assessment and the foundational contributions of Howard T. Odum in this field, the following subsection provides a detailed overview of Odum's systemic perspective and its direct influence on the 5SEnSU model adopted in this study.

1.1. The legacy of H.T. Odum and the systemic hierarchy of sustainability

Howard T. Odum (1971, 1996) pioneered a holistic way of observing complex real-world systems that he called the 'macroscope'. Rather than an optical device, the macroscope is a mental model that abstracts from excessive detail to reveal the key elements of a system and the energetic interactions among them. This approach enables a synthetic and integrated understanding of the organization, functioning, and sustainability of ecological and socio-economic systems. The macroscope well-suited to the analysis may system, incorporating the existing complexities that are often misunderstood through conventional disciplinary approaches (Giannetti et al., 2020). A notable example of the impact of this perspective is found in the special issue of *Ecological Modelling* (vol. 178, 2004), entirely dedicated to Odum's legacy.

One of the most distinctive elements of Odum's macroscope approach is the use of energy systems diagrams. Odum developed a symbolic language designed to represent the flow, storage, transformation, and dissipation of energy in open systems. This diagrammatic approach has proven especially effective for modeling biospheric systems, such as ecosystems and economies, as it is grounded in core principles like feedback, self-organization, and hierarchical organization.

A central concept of this framework is that both natural and human systems exhibit hierarchical structures, where each level corresponds to specific temporal, spatial, and energetic scales. In Odum's energy diagrams, this hierarchy is illustrated with the foundational levels positioned on the left, characterized by higher energy quantities and lower quality, and the more specialized levels on the right, where energy quality increases even as quantity decreases. Energy is transformed along this hierarchical chain, and the upper levels emerge as products of systemic self-organization. For Odum, the sustainable design of ecological and social systems must respect these hierarchies and the feedback pathways that maximize system performance (Odum, 1996).

Although the term sustainability was not central to Odum's work, the concept emerges as an emergent property of self-organizing systems, in which optimal performance occurs when energy flows are balanced with environmental carrying capacity. This perspective, typical of the natural and Earth sciences, contrasts with more common approaches in the social sciences and management, which often begin with abstract definitions of sustainability, frequently represented in conceptual models with limited biophysical grounding.

The sustainability literature is rich in visual representations that attempt to illustrate the relationship among its three classical dimensions: environmental, social, and economic. Purvis et al. (2019) conducted a critical review of these representations, showing that the

popular ‘three pillars’ model emerged gradually without rigorous theoretical foundation. These authors also noted that some models imply a hierarchy, such as the concentric circles model, in which the environment supports society, which in turn supports the economy. A striking example is [Lozano’s \(2008\)](#) model, where the environment forms the base, followed by society, and finally the economy at the center—corresponding to the hierarchy: environmental → social → economic. Another example is the ‘wedding cake’ model from the Stockholm Resilience Centre (2016), which organizes the Sustainable Development Goals (SDGs) into three hierarchical layers: the environmental foundation, the social layer in the middle, and the economy at the top. This model emphasizes that the economy depends on society, and both ultimately depend on the biosphere. Recent studies ([Fet et al., 2023](#); [Bergman et al., 2023](#)) have used this structure to reinforce the role of the environment as the sine qua non condition for the sustainable functioning of other levels.

Even in the institutional presentation of the SDGs—which adopts a visual grid structure without explicit hierarchy—an implicit ordering can be observed: SDGs 1 to 6 refer to social issues; SDGs 7 to 12 address economic topics; and SDGs 13 to 15 focus on environmental aspects. Although the official stance declares a balance among the three dimensions (United Nations General Assembly, 2015), practical implementation has favored the economic dimension, revealing an anthropocentric tendency (economocentrism), which is criticized by ecocentric perspectives and implicitly by Odum’s systemic approach (1996).

The 5SEnSU model adopts and updates this Odum’s tradition by proposing a systemic approach to sustainability assessment. Structured into five dimensions—Environment as a provider of resources, Environment as a sink for waste, Productive Unit (economic), Society as a provider of labor and inputs, and Society as a consumer of goods and services—the model explicitly acknowledges the functional hierarchy among these dimensions, grounded in the principle that energy flows and biospheric organization condition the possibilities for human and economic development. As in Odum’s diagrams, the 5SEnSU model considers the fundamental system elements (energy, environment) as the supporting base for more specialized components (economy, governance), reflecting a logic of self-organization and feedback. It is important to emphasize that the model positions society at the upper end of the hierarchy, in alignment with Odum’s interpretation of the biosphere’s organizational structure.

Through the integration of biophysical metrics and social indicators within a unified analytical framework, 5SEnSU offers a contemporary and practical application of Odum’s principles. This approach reflects his perspective on sustainability as an emergent property of living systems structured by energetic hierarchies.

In the remainder of this article, Odum’s legacy is operationalized through two main elements: (i) the use of the emergy-based efficiency indicator $GDP / Total\ Energy\ Used\ (U)$ as a core component of the Integrated Development–Emergy-Adjusted Score (IDEAS); and (ii) the graphical representation of intersector flows in energy systems diagrams consistent with Odum’s notation. These elements ensure that the methodology, metrics, and visual outputs reflect Odum’s systemic framework.

2. Methods

2.1. Case study

Mozambique is the focal point of this article’s case study, yet the new approach applies to diverse countries and their respective trade partnerships. The selection of Mozambique is rooted in its status as the least developed country in Southern Africa, as indicated by its ranking on the HDI. A significant portion of Mozambique’s population resides in poverty, heavily reliant on natural resources for sustenance ([MICOA, 2014](#)), with nearly three-quarters of its workforce engaged in

agriculture ([World Bank, 2018](#)). Following the cessation of the 1992 civil war, Mozambique witnessed a notable upsurge in GDP, leading to a gradual reduction in income disparities compared to other Sub-Saharan African nations. However, despite these advancements, high disparity persists across social sectors and within the economic framework, which, according to [Giannetti et al. \(2023\)](#), renders the country heavily dependent on local natural resources and vulnerable to external drivers.

The analysis also encompasses the Southern African Development Community (SADC) countries with which Mozambique engages in trade and the primary non-African nations that conduct trade with Mozambique. This holistic approach provides a more extensive understanding of Mozambique’s trade dynamics and its implications for both regional and international economic relationships.

2.2. The five sectors sustainability (5SEnSU) model

The 5SEnSU model in [Fig. 1](#) adopts and updates this Odum’s tradition by proposing a systemic approach to sustainability assessment. Within this framework, sector 1 embodies the environment as a source, furnishing raw materials essential for sustaining the operations of the production unit (sector 3). Conversely, sector 2 portrays the environment as a sink that absorbs waste and emissions from the production unit’s activities. Society assumes the roles of supplier and consumer within the model. In sector 4, society contributes with socio-economic resources to the production unit, encompassing vital elements such as labor, knowledge, and expertise, in exchange for monetary compensation. In turn, the production unit supplies products destined for consumption by society, which responds by providing monetary remuneration. Notably, financial transactions occur exclusively on the right side of the model of [Fig. 1](#) (dashed lines), symbolizing activities conducted by human agents. On the left side of the diagram, exchanges exclusively entail energy and/or material flows, reflecting the perception of resources provided by the natural environment as “free resources.” In this context, the production unit does not extend financial remuneration to the environment in exchange for services such as dilution and decomposition. For a deeper understanding of the 5SEnSU model, including its axioms and epistemological roots, please see [Giannetti et al. \(2019\)](#). The model explicitly acknowledges the functional hierarchy among these sectors, grounded in the principle that energy flows and biospheric organization condition the possibilities for human and economic development. As in Odum’s diagrams, the 5SEnSU model considers the fundamental system elements (energy, environment) as the supporting base for more specialized components (economy, governance), reflecting a logic of self-organization and feedback. It is important to emphasize that the model places society at the top of the

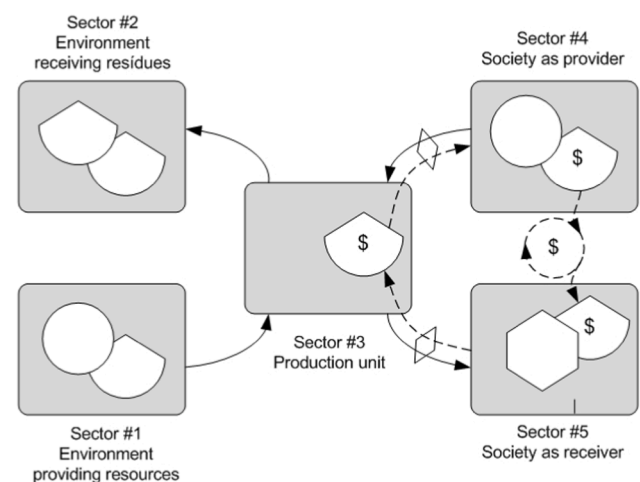


Fig. 1. Five Sustainability Sector Model (5SEnSU). Source: [Giannetti et al. \(2019\)](#).

hierarchy, reflecting Odum's interpretation of how the biosphere is structured. By incorporating biophysical metrics and social indicators within an integrated framework, the 5SEnSU model offers a modern and practical application of Odum's theoretical foundations. This structure is consistent with his understanding of sustainability as an emergent property of living systems governed by energy-based hierarchies.

The 5SEnSU model was initially applied to countries within the Mercosur economic bloc, but since its proposition, it has been used in diverse applications across various domains. Specifically, one study closely related to this present study is its utilization in diagnosing poverty traps in Mozambique, employing the theory of ecologically unequal exchange and emergy synthesis (Giannetti et al., 2023). Expanding its scope, the model has been deployed in assessing the transportation sector (Agostinho et al., 2019), evaluating water and wastewater treatment companies (Giannetti et al., 2022a), and scrutinizing the relationship between circular economy principles and the sustainability of economies (Terra et al., 2022). Furthermore, its application extends to discussions surrounding the significance of environmental, social, and governance labels for companies (Giannetti et al., 2022b) and analyzing rice production across different countries (Moreno Garcia et al., 2021). These diverse applications underscore the versatility and relevance of the 5SEnSU model in addressing multifaceted challenges across various contexts.

The application of the 5SEnSU model involves selecting indicators that should observe some principles. Social, economic, and environmental indicators must be included to maintain the model's multidimensional nature. Additionally, indicators should be aligned as much as possible within the same time frame to ensure a consistent assessment during that period. The following section presents the variables and indicators considered in this study.

The 5SEnSU model is conceptually and structurally rooted in Howard T. Odum's systems ecology and emergy framework. Its diagrammatic structure draws inspiration from Odum's energy systems language, with directional flows, sectoral roles, and feedback loops that reflect the organization of energetic hierarchies in socio-environmental systems. In particular, the placement of the natural environment as both source and sink, the productive sector as a converter of energy and matter, and society as both a driver and beneficiary of system outputs mirrors the systemic logic present in Odum's macroscopic approach. Moreover, the emphasis on emergy-based indicators, such as GDP/U, reflects a direct operationalization of Odum's proposal to assess development performance in terms of energetic investment. Thus, the model not only builds upon Odum's theoretical contributions but adapts them to the context of comparative international sustainability assessment.

2.2.1. Choice of variables and indicators

Before defining the indicators that will feed the 5SEnSU model, it is important to define the variables that, in principle, would allow an appropriate comparative macro-scale analysis among 5SEnSU sectors. The Gross Domestic Product (GDP) is the foundational variable for obtaining the five analyzed indicators. This selection aligns with the principles of the 5SEnSU model, which regards the production sector as the essential link between the environment and society. GDP or GDP per capita is the primary metric for gauging economic development (Karaalp-Orhan, 2020). The preference for GDP over other variables stems from the fact that, in a study encompassing countries, GDP serves as a macroeconomic measure of a nation's economic wealth, besides being available for different countries and along large temporal scales. According to Panzera and Postiglione (2022), disparity, particularly in terms of national or regional GDP, significantly influences a nation's economic growth trajectory. Additionally, Karaalp-Orhan (2020) further emphasizes that disparities in per capita income across regions underscore the concentration of economic activities within specific locales. Thus, the choice of GDP as the base variable underscores its significance in capturing economic dynamics and disparities at both national and global scales. This rationale aligns with Odum's (1996)

emergy theory, which highlights the role of a nation's internal emergy base in shaping its capacity for autonomous development. Within this framework, the GDP/Total emergy indicator serves as a proxy for evaluating how effectively a country transforms its available biophysical resources into economic performance. By incorporating this indicator, the 5SEnSU model directly operationalizes Odum's theoretical propositions, offering a means to assess resource efficiency from a systemic and ecological economics perspective.

While GDP serves as a commonly utilized metric in studies of disparity (Piketty, 2014; Milanovic, 2016; Atkinson, 2015), its use often engenders a narrow and somewhat misleading discourse within the broader context of sustainable development (Giannetti et al., 2015). Acknowledging its significance and seeking to engage stakeholders familiar with its implications, GDP is here considered an essential indicator. However, it is utilized comparatively, juxtaposed with other environmental and social variables considered indispensable and aligned with the 5SEnSU model and its sectors.

Once the variables are selected, the next step is determining the indicators that will be considered within the 5SEnSU model. These indicators serve as foundational elements for policy development and monitoring a country's performance concerning sustainable economic development. This endeavor aligns with the ongoing efforts of numerous studies, such as those by Colocci et al. (2023), Wendling et al. (2022), and Schandl et al. (2016), which have sought to assess countries' performance based on composite and simple performance indices across environmental, social, and economic dimensions. Building upon the chosen variables, this study considers the following indicators for all countries worldwide (Table 1): GDP/Total Emergy, GDP/CO₂-eq., GDP/Capita, GDP/Workforce, and GDP/Population below the poverty line. The chosen indicators are rooted in various sustainability strategies: (a) Enhancing GDP per unit of resource use (U), aiming for greater economic output while minimizing resource consumption. (b) Maximizing GDP while minimizing CO₂-eq. emissions, thereby elevating GDP per unit of environmental load. (c) Increasing GDP per capita signifies improvements in individual economic prosperity. (d) Boosting GDP per workforce indicates enhanced labor productivity and economic efficiency. (e) Narrowing the disparity between GDP and the population below the poverty line fosters more inclusive economic growth. (f) Striving for regional parity in performance, with all countries approaching the median performance level which fosters a sense of mutual benefit and interdependence, similar to working together as a unified group for the collective progress of their respective nations. Details regarding the definitions of the indicators in this study are presented in Table 1.

The selection of indicators was based on the expertise of the authors of this study, supported by information from the scientific literature and the availability of data. These indicators have been previously employed in analyzing country and regional scenarios concerning the interplay between climate change (carbon emissions), industrial metabolism (energy and material flows), and monetary flows, as demonstrated in studies by Schandl et al. (2016), Herman and Zsido (2023), and Rimba and Hirabayashi (2023). These indicators serve as measures of intensities, shedding light on the relationship between economic output and various environmental and social factors.

2.3. Integrated indicator of economic-environmental-social performance (IDEAS): a proposition

In this study, the IDEAS index is proposed as a global performance indicator, conceptually aligned with the 5SEnSU model. IDEAS can be considered as an indicator based on a multicriteria approach. It represents the arithmetic mean of each country's performance in the five normalized indicators constituting the 5SEnSU model: GDP/CO₂-eq., GDP/U, GDP per capita, GDP/workforce, and log GDP/Population below the poverty line. A visual depiction of the results is rendered through a spiral graphical representation, illustrating the proximity of

Table 1
Economic, social and environmental indicators for the 5SEnSU model.

Indicator	Definition	Meaning
GDP ^a /U ^c	It represents the monetary output per unit of emery demanded, derived from the ratio of GDP to total Emery (U).	This indicator illustrates the environmental-economic performance of the environmental sector as a resource supplier. It should be maximized.
GDP ^a /CO ₂ -eq ^b	It denotes the monetary value generated per CO ₂ equivalent emitted, calculated by dividing GDP by CO ₂ -eq. emissions.	This indicator reflects the environmental-economic performance of the environmental sector as a recipient of emissions. It should be maximized.
GDP ^a per capita ^d	It is calculated as the GDP divided by the population of a country, reflecting the level of economic production in a territory relative to its inhabitants.	This indicator reflects a country's economic production adjusted for its population size, indicating the perceived prosperity experienced by each citizen. It should be maximized.
GDP ^a /workforce ^e	It is determined by dividing the GDP by the country's economically active population, indicating the productivity of the workforce.	This indicator demonstrates a country's performance in how effectively its economically active population contributes to the economy through GDP. It is important to emphasize that this indicator should be maximized not by reducing the workforce, but by increasing GDP. Thus, it can be interpreted as a more efficient labor force in productive sectors that generate higher GDP. The maximization of the ratio between GDP and the workforce can be grounded in the theory of economic growth and productivity. According to Solow (1956), stable economic growth is primarily driven by increased productivity, which occurs when there is an increase in output per worker. This implies that the focus should be on increasing GDP through improvements in efficiency, technological innovation, and investments in human capital, rather than merely reducing the number of workers.
GDP ^a /Population below the poverty line ^f	Estimates the correlation between GDP and the population living below the poverty line.	This indicator illustrates the gap between a country's wealth, as measured by GDP, and its population living below the poverty line. It should be maximized.

Data and their source for the chosen indicators are obtained as follows:

^a GDP and GDP per capita (at constant 2010 US\$ prices): Calculated without accounting for the depreciation of manufactured goods or the depletion and degradation of natural resources (World Bank, 2019).

^b CO₂-eq.: Total greenhouse gas emissions, including land use change and forestry, measured in million metric tons of CO₂ equivalent (MtCO₂-eq.) (Cait Climate Data Explorer, 2017).

^c Total Emery used (U): The aggregate of renewable emery demanded from dispersed rural sources, fuels and minerals, and goods and services imported (National Environmental Accounting Database V2.0 (NEAD), 2014).

^d Total Population: Counts all residents, irrespective of legal status or citizenship (World Bank, 2019).

^e Workforce: Comprising individuals aged 15 years and older, encompassing those currently employed, those unemployed yet actively seeking employment, and those entering the workforce for the first time (International Labour Organization, 2019).

^f Population living below the poverty line: Percentage of the population living on less than US\$1.90 per day in 2011 international prices, known as the 'international poverty line' (World Bank, 2019). This threshold is applied uniformly across all countries to enable consistent international comparisons, regardless of national poverty definitions, which may vary in methodology and income thresholds.

each country to the target, as detailed in the next section. This target spans from 0.0, denoting null performance, to 1.0 in the center of the target, indicative of high performance. The calculation of country performance is conducted concerning the median statistics of >150 countries globally across the variables and indicators under examination.

The five normalized indicators were aggregated using a simple arithmetic mean, assuming equal weights across economic, environmental, and social dimensions. This choice reflects the 5SEnSU model's underlying normative principle of balance among sectors, and facilitates transparency and interpretability. However, this approach also implies full substitutability across indicators, which may not always be desirable from a policy perspective. Moreover, some indicators, such as GDP per capita and GDP per workforce, may exhibit significant correlation, potentially inflating their combined influence in the final score. Alternative aggregation strategies, such as the geometric mean—as adopted in the Human Development Index—may be more suitable in future applications, as they reduce the risk of compensatory bias and better reflect multidimensional imbalances. Future developments of the IDEAS index should also consider non-compensatory functions and weightings derived from statistical or expert-based techniques to assess the sensitivity and robustness of the results under different assumptions.

In constructing the IDEAS index, all five indicators were formulated with GDP consistently placed in the numerator. This structural choice was intentional and serves both interpretive and methodological purposes. Conceptually, it reflects a unified interpretation of development performance in terms of economic efficiency, defined as the capacity to transform physical, human, and environmental resources into monetary value. Methodologically, this approach ensures that higher indicator values represent better performance, which facilitates the normalization process by preserving consistent directionality across all metrics. While alternative formulations, such as the Emery Money Ratio (U/GDP), are valid within emery theory, they reverse this logic and would require a broader conceptual reformulation of the index. The current structure, therefore, supports both the comparability and the intuitive interpretation of the indicators within the 5SEnSU framework.

2.3.1. The normalization process and the target graphic

The indicators utilized in this study exhibit different units, necessitating their normalization based on a statistical approach to assess distribution; specifically, a boxplot diagram is considered for normalization. The boxplot illustrates the distribution of indicator values, facilitating a visual comparison of indicators chosen to express countries' overall performance (Kühnel et al., 2023). Due to a lack of consistent available data, it was not possible to include a similar number of countries/territories for all the indicators used in the analysis. Specifically, the GDP/CO₂-eq. indicator comprises 174 countries/territories globally, the GDP/Workforce indicator includes 181 countries/territories, the GDP/U indicator consists of 160 countries/territories, the GDP per capita indicator comprises 201 countries/territories, and the GDP/Population below the poverty line indicator consists of 202 countries/territories (see Supplementary Material A). The logarithmic value is considered for this last indicator because there is a huge difference between the richest and poorest countries. Fig. 2 presents the boxplots illustrating the distribution of five indicators across the sample of countries, encompassing the outliers (extreme values). In the boxplots, the ends represent the 25th and 75th quartiles. The line within the box signifies the median statistical value of the sample, providing insights into its central tendency. Additionally, an 'asterisk' denotes the sample statistical mean, accompanied by the 95 %

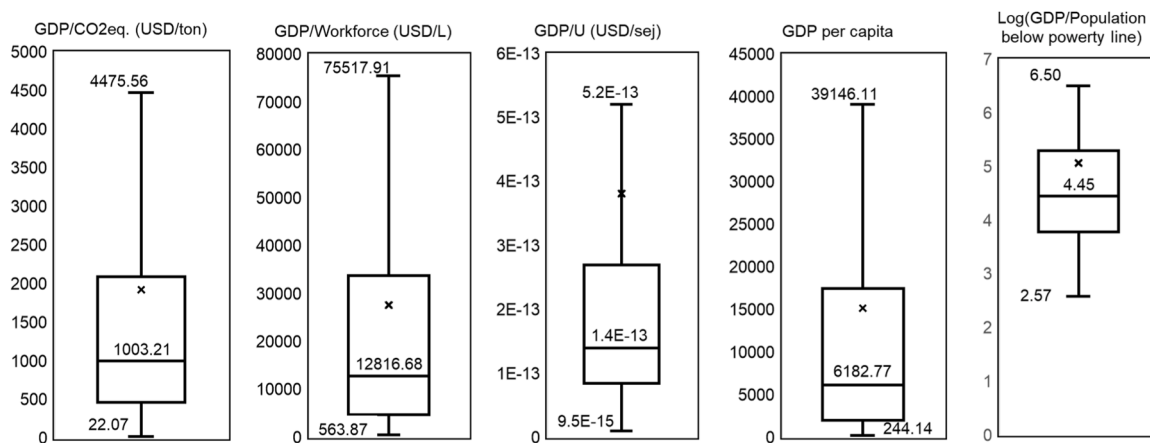


Fig. 2. Chosen indicators based on the 5SEnSU model to express countries sustainability. Original data is available in Supplementary Material A.

confidence interval, measuring the data’s dispersion and variability.

Outlier values were identified using the boxplot statistical rule, considering values beyond the interval

$Q1 - 1.5 \times IQR, Q3 + 1.5 \times IQR$ as outliers. Where:

$Q1$ = first quartile = value below which lie the lowest 25 % of the data

$Q3$ = third quartile = value below which lie 75 % of the data

IQR = interquartile range = $Q3 - Q1$ = measure of spread of the "central" data

These extreme values were excluded when determining the minimum and maximum thresholds used in the normalization scale to avoid distortion of the final index. However, countries with outlier values were not excluded from the analysis entirely, especially when they played a relevant role in Mozambique’s trade relations. In such cases, these countries were still assigned normalized scores of 1 or 0, respectively, when their indicator values fell above the upper bound or below the lower bound of the normalization range. This approach preserved the integrity of the normalization while allowing the inclusion of relevant trade partners in subsequent analyses. According to Bie et al. (2023), this approach allows the reduction of measurement differences and unit dimensions among the indicators, which is corroborated by Helbig et al. (2021), who say this approach enhances the interpretation of a country’s performance concentration.

After normalizing the indicators, the proposed ‘Performance Target Chart’ of Fig. 3 graphically represents them. This figure provides an integrated and easier view of the sustainable development challenges and opportunities for Mozambique as the baseline country compared with SADC countries and Mozambique’s trading partners.

It is proposed that interpreting a country’s performance in a given indicator involves considering four ranges. The range of 0.75 to 1.0 indicates high performance, suggesting that the country’s policies and practices align well with global (SDGs). The justification for this range is based on the concept of the ‘margin of progress’ (Meka and Venkateswarlu, 2024), where countries that reach or approach 100 % compliance with an indicator demonstrate that their policies and practices are effective and aligned with global best practices (Rockström et al., 2009). The proximity to the maximum value (1.0) suggests a robust socioeconomic and environmental environment, indicating success in public policies, governance, and sustainable management. The next interval ranges from 0.5 to 0.74, indicating average performance, reflecting a need for improvements to prevent widening disparities in relation to the SDGs. This range suggests that, although the country has made progress, significant gaps still exist in achieving the full scope of the SDGs (Marti and Cervelló-Royo, 2023). This can be explained by the term ‘critical transitions theory’ of the SDGs, coined by the same authors, where systems close to the tipping point (in terms of sustainability) require substantial interventions to prevent setbacks (United

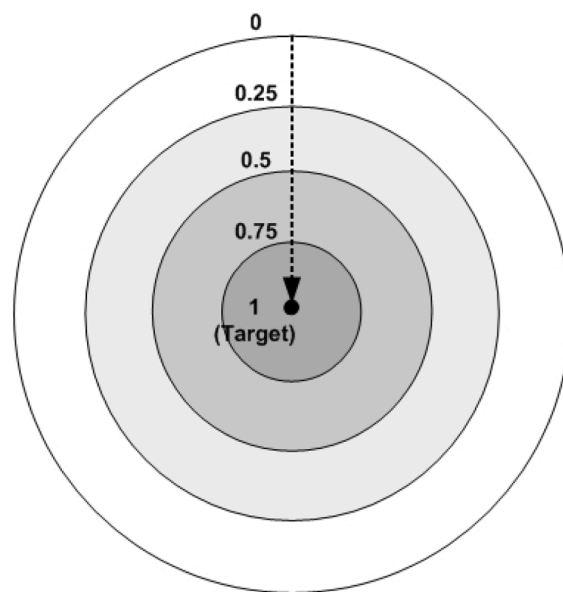


Fig. 3. The proposed ‘Performance Target Chart’ to graphically represent the comparative performance of sustainability among countries.

Nations Development Programme - UNDP, 2019). The range of 0.25 to 0.49 indicates low performance, highlighting the presence of significant challenges. Performance within this range suggests that the country faces considerable difficulties in achieving the SDGs. This can be attributed to structural deficiencies, lack of resources, or ineffective policies, a situation can be explained through the ‘theory of social and economic inertia’ (Vereshchagina et al., 2018; Pritchett, 2013) and suggests that countries or regions with low performance in indicators tend to encounter greater challenges in breaking cycles of poverty, disparity, and environmental degradation, requiring profound structural changes. The range of 0.0 to 0.24 indicates deficient performance, signaling an urgency in rethinking strategies and policies. This range represents a critical level of performance, where indicators are far below the expected threshold for achieving the SDGs. This situation can be viewed through the lens of the ‘planetary boundaries and development theory’ (Steffen et al., 2015), where countries in this range are at risk of exceeding ecological and social limits, endangering their populations’ well-being and future sustainability.

2.3.2. Maximum disparity ratio (MDR)

This paper draws on the approach of Spiezia (2003), which focuses

on evaluating performance differences between countries based on their aggregate outcomes across environmental, social, and economic dimensions. As Kogachi et al. (2021) highlight, one of the growing challenges in sustainability assessment is the design of indicators that capture multiple dimensions within a single, communicative metric. Building upon this notion, the Maximum Disparity Ratio (MDR) is introduced as a descriptive indicator to illustrate the relative performance gap between countries, particularly highlighting how far a reference country (Mozambique) is from the best-performing nations within specific regional or trade contexts.

The MDR is calculated by dividing the highest IDEAS score observed in a group by that of the reference country. This ratio does not represent disparity in a statistical sense, unlike the Gini coefficient or other distribution-based metrics, but instead provides an intuitive measure of performance disparity at the extremes. Several studies (Ren et al., 2017; Leeben et al., 2013) have emphasized the importance of global indicators for evaluating sustainability performance, and the MDR follows this line by offering a simplified view of systemic imbalance.

From the perspective of Odum's ecological systems theory, this performance gap may be interpreted as a lack of balance or equilibrium in how countries transform environmental, economic, and social capital into sustainable development outcomes. Thus, the MDR is not proposed as a standalone or statistically rigorous disparity index, but rather as a complementary and communicative tool within the IDEAS-5SEnSU framework, helping to draw attention to structural disparities that can guide integrated policy action.

3. Results and discussion

3.1. Calculating the ideas for the SADC countries

Table 2 displays the ranking and performance of Mozambique compared with other SADC countries across social, economic, and environmental indicators. Mauritius and South Africa exhibit the highest performance for IDEAS among the SADC. In contrast, countries like Madagascar and the Democratic Republic of the Congo recorded the lowest scores on the IDEAS index. Mozambique occupies the 12th position among the 14 SADC countries analyzed, with a composite score of 0.076. This result highlights a particularly low level of integrated development within the region. The overall average for the SADC bloc stands at 0.236, suggesting moderate performance across the combined economic, social, and environmental dimensions.

Data from Table 2 can be presented in the radar graph as provided in Fig. 4, illustrating the comparative countries' performance for each indicator and the 5SEnSU model's sector from 0 to 1 (or 0 % to 100 %).

Table 2
SADC countries ranked by their performance on IDEAS.

SADC countries	GDP/CO ₂ -eq.	GDP/U	GDPpc	GDP/ workforce	log(GDP/ Population below the poverty line)	IDEAS
1st Mauritius	0.654	0.821	0.565	0.574	0.669	0.651
2nd South Africa (RSA)	0.447	0.628	0.542	0.581	0.577	0.551
3rd Botswana	0.251	0.335	0.542	0.543	0.517	0.418
4th Namibia	0.404	0.087	0.516	0.542	0.497	0.345
5th Eswatini	0.602	0.047	0.409	0.517	0.350	0.291
6th Angola	0.228	0.100	0.395	0.450	0.401	0.277
7th Zimbabwe	0.141	0.363	0.092	0.086	0.172	0.147
8th Lesotho	0.383	0.034	0.117	0.129	0.224	0.135
9th Zambia	0.026	0.160	0.151	0.174	0.244	0.122
10th/11th Malawi	0.321	0.478	0.026	0.029	0.115	0.106
10th/11th Tanzania	0.071	0.186	0.062	0.059	0.275	0.106
12th Mozambique	0.103	0.243	0.027	0.029	0.129	0.076
13th Congo, D.R.	0.070	0.084	0.017	0.031	0.064	0.046
14th Madagascar	0.104	0.034	0.018	0.013	0.053	0.034
Overall SADC	0.272	0.257	0.169	0.268	0.306	0.236

Notes: Values for 2014. GDP = Gross Domestic Product. U = Total EMergy Used. GDPpc = Gross Domestic Product per capita. IDEAS = Economic-Environmental-Social Performance Indicator calculated as the geometric mean of each country's performance in the five normalized indicators. Malawi and Tanzania have the same IDEAS score (0.106), resulting in a tie for the 10th/11th position in the ranking. Raw data available in Supplementary Material A.

Regarding the performance in the economic efficiency indicator concerning CO₂-eq., Mozambique demonstrates a low score of 0.103 compared to the maximum scale, positioning itself above only Zambia, Tanzania, and the Democratic Republic of the Congo. This outcome can be explained by Mozambique's lack of a productive and industrial structure with high added value, relying instead on primary sectors such as fishing, agriculture, and mining, which have less environmental impact than industrial emissions. According to the World Bank (2018), the majority of Mozambique's CO₂-eq. emissions stem from the burning of forests. The GDP/EMergy Used indicator assesses the efficiency of resource use in economic production, where Mozambique presents a low value of 0.243, suggesting energy inefficiency. In the GDP/Workforce indicator, which measures labor productivity, Mozambique has a very low score of 0.029, indicating low labor productivity. Its GDP per capita value (0.027) also ranks among the lowest in the region, highlighting its economic vulnerability. Finally, for the population below the poverty line indicator, Mozambique scores 0.129, placing it among the worst-performing countries in terms of social inclusion. The resulting IDEAS score of 0.076 confirms a broad challenge in balancing economic performance, environmental efficiency, and social equity.

The literature supports that high disparities, such as those observed in Mozambique, are commonly associated with weaker economic growth and social development (Nguyen et al., 2019; Chetty et al., 2017). The low labor productivity and inefficiency in resource use align with structural challenges already noted in other developing regions (Nel, 2008). In Mozambique's case, such trends may indicate that a significant portion of natural and human resources remains underutilized or inefficiently integrated into value-generating systems (Fosu, 2018).

Mozambique's low resource efficiency and high CO₂ intensity are at odds with the need for sustainable development, which the literature emphasizes the importance of effective management of natural resources and ecological sustainability to improve quality of life and human development (Geng et al., 2022). Results of Fig. 4 highlight that Mozambique faces severe economic efficiency, productivity, and poverty challenges, which are consistent with the trends observed in the literature on disparity and development. The low performance of Mozambique's indicators persists despite the substantial contribution of this population to Mozambique's GDP through agricultural and mining production, where development programs that integrate economic, social, and environmental aspects are crucial (Ulman et al., 2021).

Considering all the 5SEnSU indicators, the IDEAS (Fig. 5) show Mozambique with a value of 0.106, the third lowest in the region, indicating a fragile overall performance in sustainability compared to the SADC countries. The IDEAS score for SADC indicates that Mauritius

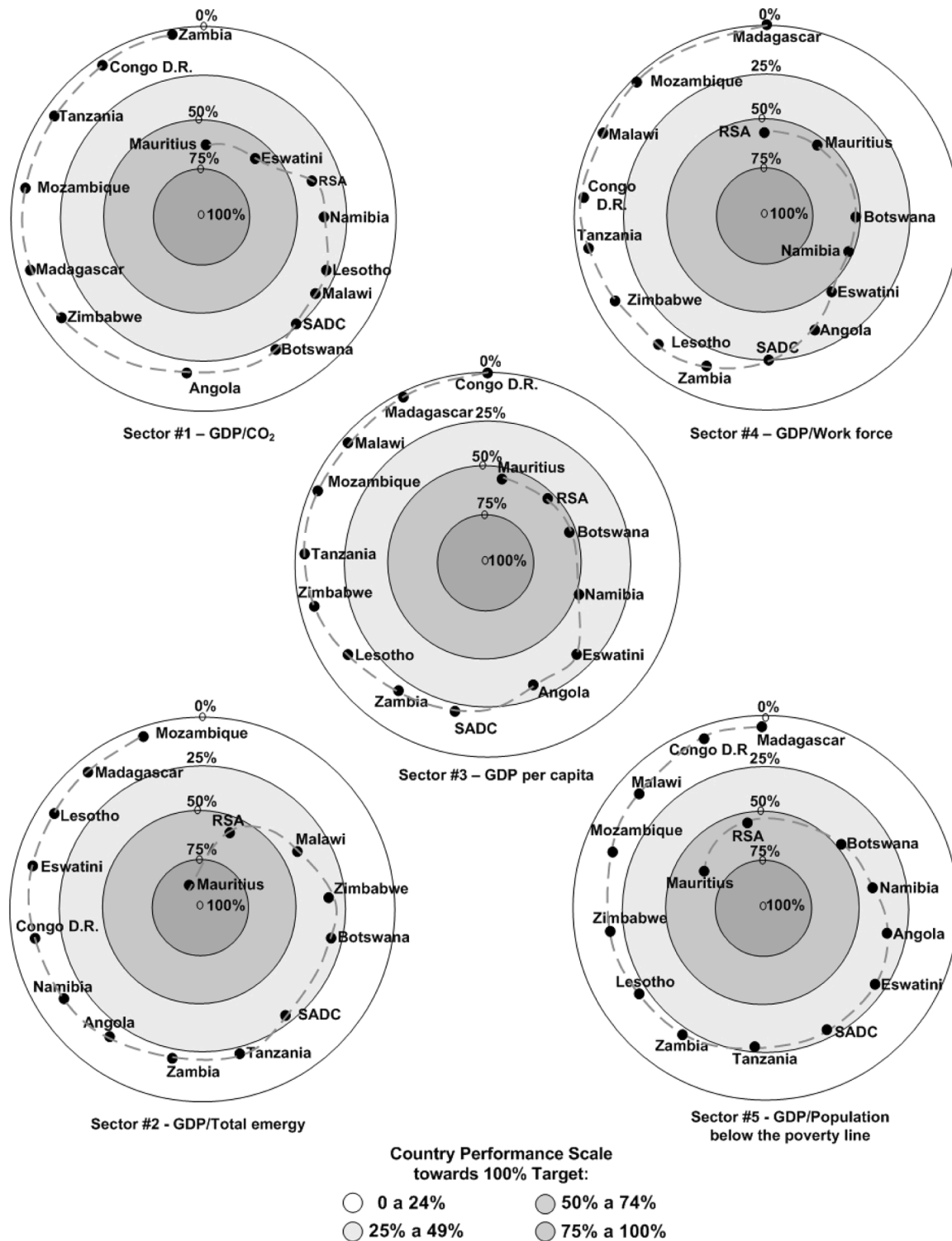


Fig. 4. Individual indicators performance for the SADC’s countries distributed across the 5SenSU Model’s sectors. Data from Table 2.

achieved a performance of 65.4 % compared to the maximum scale of 100 %, securing the top position. Robust performances influence this performance in indicators of economic efficiency, particularly GDP in relation to total energy, CO₂-eq. emissions, and population below the poverty line. South Africa follows closely with a performance of 55.1 %, placing it in the second position in IDEAS. Its performance is driven by economic efficiency indicators such as GDP to total energy (U), labor force, and population below the poverty line, which exhibit higher values than other indicators for the same country. The remaining SADC

countries exhibit low performances, influenced mainly by GDP per capita and GDP/workforce indicators, and economic efficiency indicators with CO₂-eq. emissions and population below the poverty line. A contrast between environmental indicators and economic and social indicators is evident. Environmental indicators demonstrate differentiated and high performances, potentially influencing the overall IDEAS score, particularly in comparisons among SADC countries. For instance, Mauritius, South Africa, Botswana, and Namibia exhibit higher performances in environmental indicators (GDP/CO₂-eq., GDP/U), followed by

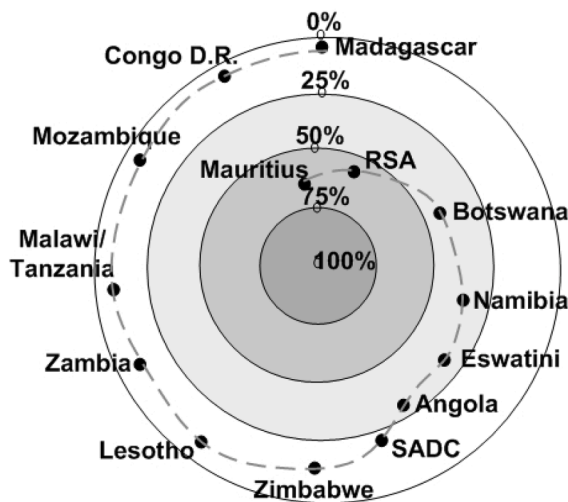


Fig. 5. IDEAS comparative performance for the SADC's countries. Data from Table 2.

economic indicators (GDP/workforce, GDP/population). In contrast, the rest of the SADC countries register average to lower scores. Fig. 5 clearly demonstrates that more than half of the SADC countries, including Mozambique, fall within the 0 to 0.24 range, placing them at risk of exceeding ecological and social boundaries, threatening both the well-being of their populations and the sustainability of future developments. SADC is positioned near the lower threshold as an economic bloc of partners, with an average performance close to 0.25 (0.236). Four countries are within the 0.25 to 0.5 range, and only two fall between 0.5 and 0.75. These results highlight this economic bloc's overall low social, economic, and environmental performance, indicating a limited capability to achieve the SDGs.

3.2. Calculating the ideas for the countries that receive Mozambique's goods exports

Table 3 displays Mozambique's ranking and performance regarding its primary trading partners, which collectively represent 80 % of the destination of exports, across social, economic, and environmental indicators. Countries like Switzerland, the United Kingdom, and the Netherlands exhibit the highest integrated performance in IDEAS. Mozambique ranks last (10th), with a score of 0.076, while the average score for its trading partners (excluding Mozambique) is 0.666, indicating a substantial disparity.

Table 3 shows that Mozambique has the lowest economic efficiency

Table 3
Mozambique's export destination countries ranked by their performance on IDEAS.

Export destination countries	GDP/CO ₂ -eq.	GDP/U	GDPpc	GDP/ workforce	log(GDP/ Population below the poverty line)	IDEAS
1st Switzerland	1.000	1.000	1.000	1.000	0.899	0.979
2nd UK	1.000	0.897	1.000	1.000	0.755	0.925
3rd Netherlands	1.000	0.587	1.000	1.000	0.830	0.866
4th Singapore	1.000	0.465	1.000	1.000	1.000	0.858
5th Spain	1.000	0.607	0.871	0.902	0.688	0.800
6th China	0.408	0.697	0.520	0.502	0.716	0.556
7th South Africa (RSA)	0.447	0.628	0.542	0.581	0.577	0.551
8th India	0.376	0.683	0.153	0.198	0.372	0.311
9th Zimbabwe	0.141	0.363	0.092	0.086	0.172	0.147
10th Mozambique	0.103	0.243	0.027	0.029	0.129	0.076
Countries excluding Mozambique	0.708	0.659	0.686	0.697	0.668	0.666

Note. Values for 2014. GDP = Gross Domestic Product. U = Total EMergy Used. GDPpc = Gross Domestic Product per capita. IDEAS = Economic-Environmental-Social Performance Indicator calculated as the geometric mean of each country's performance in the five normalized indicators. Raw data available in Supplementary Material A. Some countries included in this table (e.g., Switzerland) present outlier values for one or more indicators based on the boxplot distribution used in the normalization process. While these countries were excluded from defining the normalization limits, they were assigned normalized scores of 1.0 or 0.0 when their values were above or below the calculated bounds. Their inclusion is maintained due to their relevance as trade partners of Mozambique.

in terms of CO₂ emissions among its trade partners and export destinations. Countries like Switzerland, the United Kingdom, and the Netherlands show much higher efficiency (1.000), indicating that Mozambique has significant potential for improvement in emissions. Studies show that effective natural resource management is crucial for human development and institutional quality (Geng et al., 2022). Similarly, Mozambique demonstrates low efficiency in resource use, while countries such as Switzerland and the United Kingdom show high levels of efficiency (above 0.750), highlighting the need for Mozambique to improve its energy consumption practices. Mozambique also has the lowest labor productivity among these countries, reinforcing the need for stronger investment in education, professional training, and human capital development (Karaalp-Orhan, 2020). The GDP per capita value for Mozambique (0.027) is extremely low compared to its main export destinations, reflecting a stark difference in wealth and living conditions between Mozambique and developed countries.

Furthermore, Mozambique records a high proportion of the population living below the poverty line, in clear contrast to its trade partners, who enjoy a much more favorable economic situation. The high proportion of Mozambique's population living below the poverty line aligns with literature indicating that high disparities can result in recurring cycles of poverty and low economic growth (Nguyen et al., 2019; Chetty et al., 2017). Regarding the IDEAS of Table 3, it is suggested that Mozambique's overall performance in economic, environmental, and social terms is from 1.7 to 10 times lower than that of its main trade partners.

These disparities reflect not only economic gaps but also deeper structural asymmetries, reflecting differences in countries' access to and control over energy sources. From the perspective of Odum's emergy theory, Mozambique's low GDP/U ratio and weak resource efficiency indicators suggest a systemic dependence on external energy inflows. This structural vulnerability limits the nation's capacity to autonomously convert its environmental base into economic development, reinforcing long-standing disparities with its main trade partners.

The results of Table 3 highlight how Mozambique's position, marked by low scores in resource efficiency, labor productivity, and GDP per capita, mirrors broader patterns of international disparity (Fosu, 2009; 2017). Low performance in GDP per unit of emergy and CO₂ emissions suggests the need for targeted strategies to enhance energy efficiency and overall sustainability (Barbier, 2005). The comparative performance highlights the importance of addressing poverty, productivity, and ecological efficiency simultaneously, dimensions that appear as critical weaknesses in Mozambique's scores (Ulman et al., 2021; Giannetti et al., 2019).

Fig. 6 displays the overall performance of the IDEAS indicators for the nine countries that serve as destinations for Mozambique's exports. The IDEAS score shows Switzerland leading the ranking, followed by the

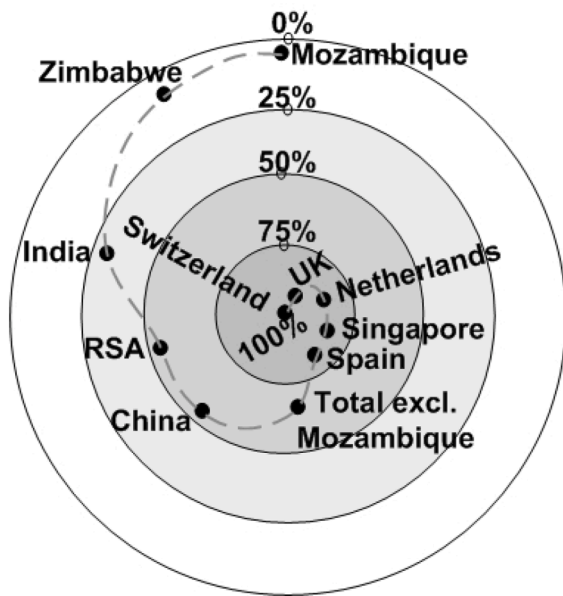


Fig. 6. IDEAS comparative performance among those countries that receives Mozambique's exports of goods. Data from Table 3.

United Kingdom and the Netherlands, all demonstrating high integrated performance. This result is largely driven by outstanding values in economic efficiency indicators, particularly those related to CO₂-eq. emissions, energy use, labor force, and poverty, many of which reach maximum normalized values. The average IDEAS score for Mozambique's trading partners (excluding Mozambique) is 0.666, while Mozambique ranks last, with a score of 0.076. Poor performance in resource efficiency, labor productivity, and poverty indicators contributes to this low result. Only Zimbabwe shows similarly low levels. These disparities are clearly evident in the radar chart presented in Fig. 6.

3.3. Calculating the ideas for the countries that export goods to Mozambique

Table 4 showcases the ranking and performance of Mozambique concerning its primary trading partners, which collectively represent 80% of the origin of imports, across social, economic, and environmental indicators. Significant disparities emerge when comparing Mozambique's results with those of its principal import partners. Japan, the USA, the Netherlands, and Germany occupy the top four positions, all

Table 4
Mozambique's origin of imports countries ranked by their performance on IDEAS.

Countries of origin of imports	GDP/CO ₂ -eq.	GDP/U	GDPpc	GDP/ workforce	Log (GDP/ Population below the poverty line)	IDEAS
1st Japan	1.000	1.000	1.000	1.000	0.761	0.947
2nd USA	0.735	1.000	1.000	1.000	0.776	0.894
3rd Netherlands	1.000	0.587	1.000	1.000	0.830	0.866
4th Germany	1.000	0.610	1.000	1.000	0.754	0.856
5th Portugal	0.870	0.624	0.751	0.766	0.667	0.731
6th Arab Emirates	0.601	0.322	1.000	0.859	0.724	0.655
7th China	0.408	0.697	0.520	0.502	0.716	0.556
8th South Africa (RSA)	0.447	0.628	0.542	0.581	0.577	0.551
9th Thailand	0.520	0.487	0.512	0.474	0.630	0.522
10th India	0.376	0.683	0.153	0.198	0.372	0.311
11th Vietnam	0.324	0.348	0.145	0.105	0.448	0.238
12th Mozambique	0.103	0.243	0.027	0.029	0.129	0.076
Countries excluding Mozambique	0.662	0.635	0.693	0.680	0.660	0.600

Note. Values for 2014. GDP = Gross Domestic Product. U = Total EMergy Used. GDPpc = Gross Domestic Product per capita. IDEAS = Economic-Environmental-Social Performance Indicator calculated as the geometric mean of each country's performance in the five normalized indicators. Raw data is available in Supplementary Material A. Some countries included in this table (e.g., Japan) present outlier values for one or more indicators based on the boxplot distribution used in the normalization process. While these countries were excluded from defining the normalization limits, they were assigned normalized scores of 1.0 or 0.0 when their values were above or below the calculated bounds. Their inclusion is maintained due to their relevance as trade partners of Mozambique.

presenting high scores across most indicators and overall IDEAS values above 0.750. Although countries like the Netherlands and Germany show moderate values in the GDP/U indicator, their strong performance in other dimensions leads to high composite scores.

Countries such as Portugal, the United Arab Emirates, China, South Africa, and Thailand show intermediate IDEAS scores ranging from 0.52 to 0.73, suggesting room for improvement in specific indicators aligned with the Sustainable Development Goals (SDGs). China demonstrates relatively low values for GDP/CO₂-eq. (0.408) and GDP per workforce (0.502), signaling areas needing significant improvement. India ranks in 10th position, with an IDEAS score of 0.356, respectively. India ranks 10th, with an IDEAS score of 0.311, marked by low values in GDP per capita and GDP per workforce. Vietnam, in 11th position, displays a particularly low IDEAS score (0.238) due to its underperformance in labor productivity and income. This low IDEAS value underscores the critical need for Vietnam to reevaluate its strategies and policies, as the current performance falls well short of the benchmarks required for substantial progress toward the SDGs. Mozambique ranks last, with a score of 0.076, reflecting widespread underperformance across all five

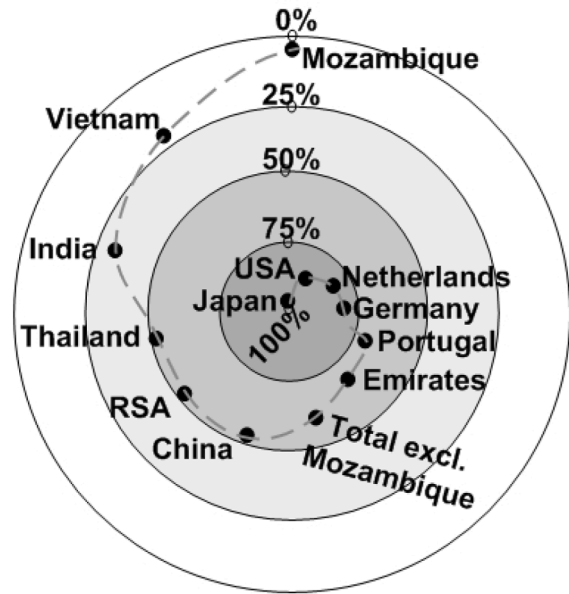


Fig. 7. IDEAS comparative performance among those countries that export goods to Mozambique.

dimensions evaluated.

Fig. 7 illustrates the overall performance of the IDEAS indicators for the countries of origin of Mozambique's imports. Japan leads the ranking with a score of 0.947, driven by near-perfect performance across all indicators except for the population below the poverty line. The USA, the Netherlands, Germany, and Portugal follow with scores above the median 0.50, reflecting balanced achievements across economic, social, and environmental dimensions. In contrast, Mozambique occupies the last position, with a score of 0.076, significantly below all its trade partners. This low performance is particularly affected by indicators related to energy efficiency, labor productivity, and poverty. Vietnam and India also exhibit low scores but remain ahead of Mozambique. The chart emphasizes the persistent disparity between Mozambique and its major import partners, with most countries clustered in medium-to-high performance ranges, while Mozambique remains in the lowest tier (0–0.24).

3.4. Disparities between the ideas for the three scenarios evaluated: SADC, exporting and importing countries

The disparities between performances were assessed using the proposed Maximum Disparity Ratio (MDR). Based on the data from Tables 2, 3, and 4, Table 5 illustrates the gap between Mozambique's IDEAS score and those of the two highest-performing countries in each trade scenario: within the SADC bloc, among export destinations, and among import origins. The MDR is calculated by dividing each country's IDEAS score by that of Mozambique. This ratio indicates how many times higher the performance of top-ranking countries is compared to Mozambique. It provides a simple yet effective way to express systemic imbalance in sustainability performance.

According to Table 5, countries such as Switzerland, the United Kingdom, Japan, and the United States present Maximum Disparity Ratios (MDRs) greater than 11, revealing significantly higher levels of economic, environmental, and social performance compared to Mozambique. Switzerland, for example, reaches an IDEAS score of 0.979, which is nearly 13 times greater than Mozambique's score. Similar disparities are observed for Japan (0.947) and the United States (0.894), with ratios of 12.46 and 11.76, respectively. Within the SADC region, Mauritius (0.651) and South Africa (0.551) also show notable advantages over Mozambique (0.076), with MDRs of 8.57 and 7.25. These figures reflect more efficient and balanced management of resources across sectors in those countries. Such findings are consistent with the work of Fosu (2009, 2017), who highlights the role of well-structured policies and effective governance in reducing regional disparity.

Disparities can also be observed in wealth, income levels, standards of living, and overall economic development. Mozambique's weak performance, particularly in the GDP/U metric, is closely tied to its reliance on exporting unprocessed primary goods, which limits value

Table 5
Disparities between maximum performances on IDEAS^a indicator among the SADC, Destination, and Origin countries compared to Mozambique.

Countries	SADC ^a	Destination countries ^b	Countries of origin ^a	Maximum Disparity Ratio (MDR) ^b
Mauritius	0.651	-	-	8.57
South Africa	0.551	-	-	7.25
Switzerland	-	0.979	-	12.88
UK	-	0.925	-	12.17
Japan	-	-	0.947	12.46
USA	-	-	0.894	11.76
Mozambique	0.076	-	-	-

^a IDEAS values from Tables 2, 3 and 4.

^b Maximum Disparity Ratio (MDR) = Highest IDEAS value / Mozambique's IDEAS value (0.076).

creation within domestic sectors. This pattern contributes to low productivity and constrained economic advancement.

The data highlight profound imbalances across social, economic, and environmental dimensions. While the MDR is not a formal statistical measure, it provides a practical overview of performance gaps, aligning conceptually with Odum's notion of systemic disequilibrium. It helps communicate the extent to which countries like Mozambique remain distant from sustainability benchmarks, emphasizing the need for integrated and context-sensitive policy strategies. This low performance in resource exploitation and utilization can be explained by the Emergy Money Ratio (EMR) theory proposed by Odum (1996). This ratio captures the amount of emergy investment required to generate a monetary unit, indicating that countries with lower EMR tend to have weaker returns from their environmental base. Mozambique faces a disadvantage in the trade of raw materials (real wealth) as it sells them at low prices to developed countries, failing to add value domestically, hence leading to poor performance. The country's performance in the GDP/Population indicator below the poverty line is supported by Barbier (2005; 2010), who argues that a significant portion of the population in low-income economies like Mozambique tends to rely heavily on the environment for subsistence. This reliance primarily serves as a lifeline for the rural poor, widening the gap from the GDP for these populations and indicating that a substantial portion of production is geared towards subsistence markets. Therefore, achieving an equitable balance between Mozambique and its trading partners requires considering all aspects of their relationship, including factors like exchanging technical and cultural information. Given Mozambique's clear lower environmental impacts associated with a very low GDP relative to natural resources, the challenge lies in increasing GDP while emitting less CO₂-eq., thereby reducing environmental pressure and improving overall performance.

Overall, the results reveal disparities in Mozambique's performance compared to its trading partners, which are inherently countries with advanced social, economic, and environmental development levels. These findings allow several observations. There is significant social, economic, and environmental disparity between the developed countries analyzed and Mozambique, a country facing economic challenges. This disparity underscores notable discrepancies in various developmental aspects and well-being between these nations, including those within the SADC region that exhibit varying levels of prosperity and natural resource availability. Examining each dimension individually reveals economic disparity, evident in differences in GDP per capita, resource access, and employment opportunities. In the social sphere, marked disparities in living standards are apparent, reflecting variations in employment access and welfare conditions among countries.

Consequently, Mozambique may encounter challenges in providing its citizens with adequate education and healthcare infrastructure, leading to a reduced quality of life compared to SADC countries and its commercial partners with superior performance. Environmental disparities suggest that within the specified timeframe, Mozambique disproportionately grapples with environmental issues such as air and water pollution, deforestation, and the impacts of climate change, primarily due to its reliance on natural resource extraction. This poses a significant challenge for impoverished nations like Mozambique. An important observation pertains to the SADC countries. When comparing the performance of SADC nations with that of Mozambique's trade partners, it becomes clear that the latter are significantly more developed. Despite this contrast, SADC countries continue to lag across the three assessed dimensions, revealing structural challenges that hinder both Mozambique and the broader region from advancing toward sustainable development and improved population well-being. The observed disparities underscore structural imbalances that align with the literature on disparity and resource dependence. These gaps suggest that improving socioeconomic outcomes in countries like Mozambique may require context-sensitive strategies aligned with sustainability principles.

These differences in performance can be explained by the differences in GDP that the wealthier countries possess. According to Ravallion (2001), Barbier (2010) and Auty (2001), lower GDP leads to direct or indirect effects, harming poverty reduction efforts and stabilization policies, weak access to natural resources by poor populations, and the dependence of GDP on mineral resources to support their economies. The increase in Mozambique's GDP growth needs to be accompanied by a reduction in CO₂-eq. emitted, as well as by creating conditions to reduce the number of people living below the poverty line. The indicators considered for improvement are those that have shown unfavorable performance compared to the SADC countries and Mozambique's trading partners. The factors of disparity can be addressed through policies of inclusive growth (increasing employment opportunities and productivity of the poorest segments of society) and human development, such as moderating fertility, improving education, reducing gender imbalances, and creating conditions to increase market access for the poor population (Stiglitz, 2012; UNDP, 2020).

The pursuit of performance goals for Mozambique would be achieved through cooperation with developed countries (those that outperform in IDEAS performance) to transfer knowledge and technology, thus strengthening key internal sectors of the economy. Therefore, Mozambique lags in economic and environmental efficiency compared to developed countries. This indicates that Mozambique is not effectively utilizing its natural resources to generate economic wealth, as evidenced by its poor performance in CO₂-eq efficiency, total energy, GDP per capita, and labor force indicators.

The disparities observed suggest that countries with performance profiles similar to Mozambique may benefit from integrated development strategies that simultaneously address economic, social, and environmental challenges. Investments in clean energy and green technologies emerge as potential alternatives to enhance energy efficiency and reduce CO₂ emissions, aligning with SDGs (Fosu, 2018). Furthermore, improvements in education and workforce training are crucial for increasing productivity and GDP per capita, as highlighted by Karaalp-Orhan (2020).

These results support the idea that systemic sustainability cannot be fully understood without accounting for the energetic and biophysical constraints that shape development pathways. Odum's framework reminds us that improving performance in economic and social dimensions must be grounded in the real limits and potentials of ecological systems.

3.5. Comparison between ideas and HDI rankings

While the Human Development Index (HDI) remains a widely recognized benchmark for assessing human well-being through health, education, and income indicators, it does not explicitly incorporate environmental dimensions or key elements of systemic efficiency into sustainability-oriented diagnostics. In contrast, the IDEAS index, based on the 5SEnSU model and H.T. Odum's energy theory, captures the functional integration of environmental, economic, and social domains through biophysical indicators. Rather than replacing the HDI, the IDEAS index is designed to complement it by revealing structural constraints and ecological tradeoffs that are often overlooked by conventional metrics. Combining both indices allows for a more holistic and integrated view of national development and sustainability. An interesting comparison emerges when IDEAS values are compared with HDI scores, as this shows how countries can perform differently depending on which dimension is being prioritized, human well-being or systemic sustainability. Table 6 presents the HDI values for the year 2014 (UNDP), together with the corresponding IDEAS index scores.

The position of countries differs substantially between the IDEAS index and the HDI because of their different assessment criteria. The HDI values of Switzerland Japan and the Netherlands match their strong positions in the IDEAS index. The relationship between these indicators does not follow a straight line because there are significant exceptions.

Table 6

IDEAS and HDI (2014 base) scores for SADC countries and their main trade partners.

SADC Country	IDEAS	HDI
Mauritius	0.651	0.788
South Africa (RSA)	0.551	0.714
Botswana	0.418	0.683
Namibia	0.345	0.619
Eswatini	0.291	0.56
Angola	0.277	0.565
Zimbabwe	0.147	0.539
Lesotho	0.135	0.500
Zambia	0.122	0.557
Malawi	0.106	0.493
Tanzania	0.106	0.506
Mozambique	0.076	0.438
Congo, D.R.	0.046	0.450
Madagascar	0.034	0.497
Export destination countries	IDEAS	HDI
Switzerland	0.979	0.951
UK	0.925	0.924
Netherlands	0.866	0.931
Singapore	0.858	0.932
Spain	0.800	0.884
South Africa (RSA)	0.556	0.714
China	0.551	0.732
India	0.311	0.611
Zimbabwe	0.147	0.539
Countries of origin of imports	IDEAS	HDI
Japan	0.947	0.910
USA	0.894	0.923
Netherlands	0.866	0.931
Germany	0.856	0.942
Portugal	0.731	0.847
Arab Emirates	0.655	0.853
China	0.556	0.732
South Africa (RSA)	0.551	0.714
Thailand	0.522	0.785
India	0.311	0.611
Vietnam	0.238	0.693

The two indexes show substantial variations in their rankings between different countries. The United Arab Emirates along with China and Vietnam demonstrate medium to high HDI levels yet their IDEAS scores remain low. This contrast suggests that, although these countries have made progress in areas such as health, education, and income, their development may rely on socioecological structures that are either not sustainable or inefficient from an energy and environmental standpoint.

The IDEAS index, in turn, reshapes the traditional ranking of countries typically seen in the HDI. Countries like Japan and the Netherlands stand out due to their stronger performance in energy efficiency and environmental indicators. In contrast, other countries that score well in the HDI end up in lower positions when systemic sustainability is considered.

The SADC region shows most of its countries performing poorly in both indices. The HDI and IDEAS scores of Mozambique and Madagascar and the Democratic Republic of the Congo remain at low levels. The combination of vulnerabilities indicates that these countries require development strategies which enhance quality of life while implementing measures to strengthen their systemic resilience.

The research confirms that IDEAS and HDI serve as separate yet useful assessment tools. The HDI measures human well-being outcomes but IDEAS evaluates the sustainability of underlying systems and processes. The combined analysis of these indicators enables a more complete understanding of national performance while revealing development paths that appear promising at first but may not endure in the long run.

3.6. Limitations and suggestions for future efforts

Some limitations in this study deserve future developments. Firstly,

the study is confined to a single year (2014) of research, implying that further analyses could replicate the findings using the same indicators over a more extended historical period.

Secondly, there is room for constructing more relationships between the utilized indicators for the simulations conducted here, particularly considering the three studied scenarios. In the modeling presented here, the 5SEnSU model indicators were considered independent; however, it is suggested as a future effort to examine one indicator's influence on another. In this case, decisions could be better supported in achieving overall performance improvements for the sustainability of the studied nation, focusing on indicators that yield the most outstanding results with the least effort. This type of hierarchy is fundamental to assist in decision-making processes.

A final suggestion would be to conduct a regional breakdown at the African level, not solely based on trade volume but also encompassing factors such as dependency on natural resources, income levels, vulnerability in fertility rates, and access to primary education. Such an analysis could help illuminate intersectoral relationships and development disparities within the region, providing complementary perspectives to the IDEAS framework. Similar considerations could extend to the breakdown of trading partners for these countries.

4. Conclusions

Considering the proposed approach and its application in this study, the following conclusions can be drawn:

- (1) When comparing Mozambique to other SADC countries, the results indicate low performance across all indicators. With an IDEAS score of 0.076, Mozambique ranks 12th out of 14 SADC countries, exhibiting the second lowest level of integrated socioeconomic and environmental performance. The Maximum Disparity Ratio (MDR) reaches 8.57, comparing Mozambique with Mauritius, the top-performing SADC country, highlighting profound regional disparities.
- (2) In relation to its main export destinations, Mozambique presents significant gaps in resource efficiency, labor productivity, and GDP per capita. Switzerland, for example, achieves an IDEAS score of 0.979, resulting in a disparity 12.88 times greater than Mozambique's performance. Even the lowest-performing export destination, Zimbabwe, scores 0.147, nearly double Mozambique's value. These findings reveal stark disparities between Mozambique and its trading partners.
- (3) A similar trend is observed regarding the countries that export goods to Mozambique. Japan, the top-ranked country in this group, reports an IDEAS score of 0.947, leading to a disparity of 12.46 times. Even Vietnam, the lowest in this group, scores 0.238, more than three times Mozambique's value. Mozambique again ranks last among its trade partners.

This paper makes several significant contributions to the field of disparity measurement and sustainable development. First, it introduces a comprehensive methodological framework based on the 5SEnSU model, enabling a quantitative assessment of socioeconomic and environmental disparities, particularly within the SADC region and its trading relationships. Second, it proposes the IDEAS index—an integrated indicator that captures economic, environmental, and social performance in a unified metric. Third, the results are visually represented through a spiral graphic, illustrating each country's proximity to a performance target and helping to identify structural challenges and priority policy areas.

Beyond offering a multidimensional metric of performance, the proposed approach sheds light on the systemic nature of international disparities. By incorporating emergy-based indicators, particularly GDP/U, the analysis reveals structural dependencies often overlooked in conventional economic assessments. This supports the notion that

sustainable development is inherently linked to a nation's biophysical foundation, with emergy availability playing a decisive role in shaping long-term socioeconomic outcomes.

Future research could expand the model's application by incorporating historical time series, regional breakdowns, and intersectoral relationships among indicators. These efforts would support more nuanced insights into the dynamics of disparity and sustainability. Overall, the study provides a robust and operational framework that not only reveals the magnitude of existing disparities but also offers valuable insights for policymakers to formulate targeted, integrative strategies. By incorporating emergy theory and the 5SEnSU structure, the approach goes beyond conventional metrics, highlighting structural vulnerabilities that must be addressed to achieve sustainable and equitable development.

CRedit authorship contribution statement

Estêvão Salvador Langa: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Biagio F. Giannetti:** Supervision, Formal analysis, Conceptualization. **Fábio Sevegnani:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Feni Agostinho:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Cecília M.V.B. Almeida:** Formal analysis, Methodology, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors are grateful for the financial support received from 'Vice-Reitoria de Pós Graduação da Universidade Paulista' (UNIP). ESL is grateful to the scholarship provided by 'Coordenação de Aperfeiçoamento de Pessoal de Nível Superior' - Brasil (CAPES - Finance Code 001). FA is grateful to the financial support provided by CNPq Brazil (305593/2023-4).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.ecolmodel.2025.111287](https://doi.org/10.1016/j.ecolmodel.2025.111287).

Data availability

Data will be made available on request.

References

- African Development Bank (ADB). (2015a). Growth, poverty and inequality nexus: overcoming barriers to sustainable development. [Online]. <https://www.afdb.org/en/documents/document/african-development-report-2015-growth-poverty-and-inequality-nexus-overcoming-barriers-to-sustainable-development-89715/>.
- African Development Bank (ADB). (2015b). Transition towards green growth in Mozambique: policy review and recommendations for action, Tunisia.
- Agostinho, F., Silva, T.R., Almeida, C.M., Liu, G., Giannetti, B.F., 2019. Sustainability assessment procedure for operations and production processes (SUAPRO). *Sci. Total Environ.* 685, 1006–1018.
- Atkinson, A.B., 2015. *Inequality: What Can be Done?* Harvard University Press.
- Auty, R.M., 2001. The political economy of resource-driven growth. *Eur. Econ. Rev.* 45 (4–6), 839–846.
- Barbier, E.B. (2012). Natural capital, ecological scarcity and rural poverty (English). Policy Research working paper; no. WPS 6232. Washington, DC: World Bank; 2012. <http://documents.worldbank.org/curated/en/277711468135304847/Natural-capital-ecological-scarcity-and-rural-poverty>.
- Barbier, E.B., 2010. Poverty, development and environment. *Environ. Dev. Econ.* 15, 635–660.

- Barbier, E.B., 2005. *Natural Resources and Economic Development*. Cambridge University Press, Cambridge, 2005.
- Bergman, M., Vass, L., Tegmark, M., et al., 2023. Linking sustainable good health and wellbeing to the SDGs. In: Filho, M.Leal, et al. (Eds.), *Good Health and Well-Being: Encyclopedia of the UN Sustainable Development Goals*. Springer. https://doi.org/10.1007/978-3-319-95681-7_105 (pp. xx–xx).
- Bie, Q., Wang, S., Qiang, W., Ma, X., Gu, Z., Tian, N., 2023. Progress toward Sustainable Development Goals and interlinkages between them in Arctic countries. *Heliyon*. 9 (2).
- CAIT - Climate Data Explorer. (2017). Washington, DC: World Resources Institute. Available online at: <http://cait.wri.org>.
- Chetty, R., Grusky, D., Hell, M., Hendren, N., Manduca, R., Narang, J., 2017. The fading American dream: trends in absolute income mobility since 1940. *Science* (1979) 356 (6336), 398–406.
- Colocci, A., Gioia, E., Casareale, C., Marchetti, N., Marincioni, F., 2023. The role of sustainable energy and climate action plans: synergies with regional sustainable development strategies for a local 2030 agenda. *Environ. Dev.* 47, 100894.
- Das, M., Basu, S.R., 2022. Understanding the relationship between income inequality and pollution: a fresh perspective with cross-country evidence. *World Dev. Perspect.* 26, 100410.
- Doyle, Michael W., Stiglitz, Joseph E., 2014. Eliminating extreme inequality: a sustainable development goal, 2015–2030. *Ethics Int. Aff.* V.28.1 https://www.carnegiecouncil.org/publications/journal/28_1/001/000002.
- Fet, A.M., Knudson, H., Keitsch, M., Fet, A.M., 2023. Sustainable development goals and the CapSEM model. *Business Transitions: A Path to Sustainability*. Springer, pp. 29–34. https://link.springer.com/chapter/10.1007/978-3-031-22245-0_3.
- Floerke, M.H., Spatafora, M.N., Venables, A., 2021. Regional disparities, growth, and inclusiveness. *International Monetary Fund*.
- Fosu, A.K., 2018. The recent growth resurgence in Africa and poverty reduction: the context and evidence. *J. Afr. Econ.* 27 (1), 92–107.
- Fosu, A.K., 2009. Inequality and the impact of growth on poverty: comparative evidence for Sub-Saharan Africa. *J. Dev. Stud.* 45 (5), 726–745.
- Fosu, A.K., 2017. Growth, inequality, and poverty reduction in developing countries: recent global evidence. *Res. Econ.* 71 (2), 306–336.
- Geng, Y., Rao, P., Sharif, A., 2022. Natural resource management and ecological sustainability: dynamic role of social disparity and human development in G10 economies. *Resour. Policy*. 79, 103050.
- Giannetti, B.F., Langa, E.S., Almeida, C.M., Agostinho, F., de Oliveira Neto, G.C., Lombardi, G.V., 2023. Overcoming poverty traps in Mozambique: quantifying inequalities among economic, social and environmental capitals. *J. Clean. Prod.* 383, 135266.
- Giannetti, B.F., Sevegnani, F., García, R.R., Agostinho, F., Almeida, C.M., Coscieme, L., Liu, G., Lombardi, G.V., 2022a. Enhancing the assessment of cleaner production practices for sustainable development: the five-sector sustainability model applied to water and wastewater treatment companies. *Sustainability*. 14 (7), 4126.
- Giannetti, B.F., Scarpelin, J., Di Agustini, C.A., Paranhos, M.A., Lozano, P.A., Agostinho, F., Almeida, C.M., 2022b. Perceived Value Versus Real value: Why can Investors in Sustainable Companies Fail in Their Mission?, 3. *Cleaner Production Letters*, 100020.
- Giannetti, B.F., Agostinho, F., Almeida, C.M.V.B., Sevegnani, F., 2020. Conceptual analysis on the way Brazilian cities work: a macroscopic view. *Front. Sustain. Cities*. 2. <https://doi.org/10.3389/frsc.2020.00013>. Article 13.
- Giannetti, B.F., Sevegnani, Fábio, Almeida, Cecília M.V.B., Agostinho, Feni, García, Roberto R.Moreno, Liu, Gengyuan, 2019. Five sector sustainability model: a proposal for assessing sustainability of production systems. In: *Ecol. Modell.*, 406, pp. 98–108.
- Giannetti, B.F., Agostinho, F., Almeida, C.M.V.B., Huising, D., 2015. A review of limitations of GDP and alternative indices to monitor human wellbeing and to manage eco-system functionality. *J. Clean. Prod.* 87, 11–25.
- Hao, Y., Chen, H., Zhang, Q., 2016. Will income inequality affect environmental quality? Analysis based on China's provincial panel data. *Ecol. Indic.* 67, 533–542. <https://doi.org/10.1016/j.ecolind.2016.03.025>.
- Helbig, C., Bruckler, M., Thorenz, A., Tuma, A., 2021. An overview of indicator choice and normalization in raw material supply risk assessments. *Resources* 10 (8), 79.
- Herman, E., Zsido, K.E., 2023. The financial sustainability of retail food SMEs based on financial equilibrium and financial performance. *Mathematics* 11 (15), 3410.
- ILO - International Labour Organization - OIT -2019. <https://data.worldbank.org/indicator/SL.TLF.TOTL.IN>.
- Islam, S.N., 2015. Inequality and Environmental Sustainability. Department of Economic & Social Affairs. DESA Working Paper No. 145ST/ESA/2015/DWP/145, August 2015.
- Karaalp-Orhan, H.S., 2020. Regional disparities in Turkey: a socio-economic perspective. *Euro. J. Sustain. Dev.* 9 (3), 103–103.
- Kogachi, E., Ferreira, A., Cavalcante, C., Embiruçu, M., 2021. Development of performance evaluation indicators for table grape packaging units. 2. *Global Indexes. Sustainability* 13 (11), 6367.
- Kühnel, K., Schütte, P., Bach, V., Franken, G., Finkbeiner, M., 2023. Correlation analysis of country governance indicators and the magnitude of environmental and social incidents in mining. *Resour. Policy*. 85, 103762.
- Lakner, C., Mahler, D.G., Negre, M., Prydz, E.B., 2022. How much does reducing inequality matter for global poverty? *J. Econ. Inequal.* 20, 559–585. <https://doi.org/10.1007/s10888-021-09510-w>.
- Leeben, Y., Soni, P., Shivakoti, G.P., 2013. Indicators of sustainable development for assessing performance of pineapple canneries: conceptual framework and application. *J. Food Agric. Environ.* 11, 100–109.
- Lozano, R., 2008. Envisioning sustainability three-dimensionally. *J. Clean. Prod.* 16 (17), 1838–1846. <https://doi.org/10.1016/j.jclepro.2008.02.008>.
- Marti, L., Cervelló-Royo, R., 2023. Disparities in sustainable development goals compliance and their association with country risk. *Sustain. Dev.* 31 (4), 3038–3051.
- Meka, J.S., Venkateswarlu, P., 2024. Progress, challenges, and strategies towards attaining sustainable Development goals. *Educ. Admin.: Theory Pract.* 30 (4), 2145–2161.
- Melamed, C., Samman, E., 2013. *Equity, Inequality, and Human Development in a Post-2015 Framework*. UNDP, New York.
- MICOA Ministry for the Coordination Of Environmental Affairs. (2014). *Final Evaluation of The Poverty And Environment Initiative (Pei), Phase II In Mozambique*. Republic Of Mozambique, Maputo, 2014. Available at: <https://info.undp.org/docs/pdc/Documents/MOZ/EVALUATION%20OF%20PEI%20I%20in%20Mozambique%20FI%20REPORT.pdf> em (08/05/2018).
- Milanovic, B., 2016. *Global Inequality: a New Approach for the Age of Globalization*. Harvard University Press.
- Moreno Garcia, R.R., Giannetti, B.F., Agostinho, F., Almeida, C.M.V.B., Sevegnani, F., Parra Pérez, K.M., Velasquez, L., 2021. Assessing the sustainability of rice production in Brazil and Cuba. *J. Agric. Food Res.* 4, 100152.
- NEAD (2014). *National energy accounting database – Country data*. Retrieved from <http://www.energy-nead.com/country/data> [Accessed 25 June 2025].
- Nel, P., 2018. Inequality in Africa. In: Binns, T., Lynch, K., Nel, E. (Eds.), *The Routledge Handbook of African Development*. Routledge, Abingdon, UK, pp. 649–662.
- Nel, P., 2008. *The Politics of Economic Inequality in Developing Countries*. Palgrave Macmillan, Houndmills.
- Nguyen, T.T., Nguyen, T., Hoang, V., Wilson, C., Managi, S., 2019. Energy transition, poverty and inequality in Vietnam. *Energy Policy* 132, 536–548. <https://doi.org/10.1016/j.enpol.2019.06.001>.
- Öberg, C., Aronsson, H., 2022. The fair trade of environmental effects and regional disparities. *Ind. Market. Manag.* 105, 311–321.
- Odum, H. T., 1996. *Environmental Accounting: Energy and Environmental Decision Making*. John Wiley & Sons, New York.
- Odum, H. T., 1971. *Environment, Power, and Society*. Wiley, New York, p. 331.
- Odosola, A., Cornia, G.A., Bhorat, H., Conceição, P., 2017. *Income Inequality Trends in Sub-Saharan Africa: Divergence, Determinants and Consequences*. United Nations Development Programme (UNDP), New York.
- Panzera, D., Postiglione, P., 2022. The impact of regional inequality on economic growth: a spatial econometric approach. *Reg. Stud.* 56 (5), 687–702.
- Piketty, T., 2014. *Capital in the Twenty-First Century*. Harvard University Press.
- Pozo, C., Galán-Martín, A., Cortés-Borda, D., Sales-Pardo, M., Azapagic, A., Guimerà, R., Guillén-Gosálbez, G., 2020. Reducing global environmental inequality: determining regional quotas for environmental burdens through systems optimisation. *J. Clean. Prod.* 270, 121828.
- Pritchett, L. (2013). The rebirth of education: schooling ain't learning center for global development. Disponivel em: <https://www.cgdev.org/sites/default/files/rebirth-of-education-brief-lant-pritchett.pdf>.
- Purvis, B., Mao, Y., Robinson, D., 2019. Three pillars of sustainability: in search of conceptual origins. *Sustain. Sci.* 14, 681–695. <https://doi.org/10.1007/s11625-018-0627-5>.
- Ravallion, M., 2001. Growth, inequality and poverty: looking beyond averages. *World Dev.* 29 (11), 1803–1815.
- Ren, J., Liang, H., Chan, F.T., 2017. Urban sewage sludge, sustainability, and transition for Eco-City: multi-criteria sustainability assessment of technologies based on best-worst method. *Technol. Forecast. Soc. Change* 116, 29–39.
- Rice, P., Venables, A., 2003. Equilibrium regional disparities: theory and British evidence. *Reg. Stud.* 37 (6–7), 675–686.
- Rimba, A.B., Hirabayashi, Y., 2023. Interlinkages of water-related SDG indicators globally and in low-income countries. *Water*. (Basel) 15 (4), 613.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Foley, J.A., 2009. A safe operating space for humanity. *Nature* 461 (7263), 472–475.
- SADC - Southern African Development Community. (2020). *SADC demographics and social statistics 2019*. 150p Gaborone, Botswana. <https://www.sadc.int/pages/sadc-statistics>.
- Schandl, H., Hatfield-Dodds, S., Wiedmann, T., Geschke, A., Cai, Y., West, J., Newth, D., Baynes, T., Lenzen, M., Owen, A., 2016. Decoupling global environmental pressure and economic growth: scenarios for energy use, materials use and carbon emissions. *J. Clean. Prod.* 132, 45–56.
- Solow R.M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*.
- Spiezia, Vincenzo. (2003). *Measuring regional economies*. Statistics Directorate of the OECD, Statistics Brief' No. 6.
- Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the Anthropocene: the great acceleration. *Anthropoc. Rev.* 2 (1), 81–98.
- Stiglitz, J.E., 2012. *The Price of Inequality: How today's Divided Society Endangers Our Future*. WW Norton & Company.
- Stockholm Resilience Centre. (2016, June 14). *The SDGs wedding cake*. <https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html>.
- Storper, M., 2018. Separate worlds? Explaining the current wave of regional economic polarization. *Spatial Transform.* 136, 247–270.
- Teixidó-Figueroas, J., Steinberger, J.K., Krausmann, F., Haberl, H., Wiedmann, T., Peters, G.P., Kastner, T., 2016. International inequality of environmental pressures: decomposition and comparative analysis. *Ecol. Indic.* 62, 163–173.
- Terra, L.C., Giannetti, B.F., Agostinho, F., Almeida, C.M.V.B., 2022. Using the five sectors sustainability model to verify the relationship between circularity and sustainability. *J. Clean. Prod.* 366, 132890.

- Ulman, S.R., Mihai, C., Cautisanu, C., Brumă, I.S., Coca, O., Stefan, G., 2021. Environmental performance in EU countries from the perspective of its relation to Human and economic wellbeing. *Int. J. Environ. Res. Public Health* 18 (23), 12733.
- UNCTAD - United Nations Conference on Trade and Development. (2018). Selected sustainable development trends in the least developed countries 2018. Geneva. https://unctad.org/en/PublicationsLibrary/aldc2018d1_en.pdf.
- UNDP, 2020. Human Development Report 2020: The Next Frontier – Human Development and the Anthropocene. United Nations Development Programme.
- UNDP - United Nations Development Programme, 2019. Human Development Report 2019: Beyond income, Beyond averages, Beyond Today. UNDP, New York.
- UNEP, 2012. Measuring Progress towards an Inclusive Green Economy. UN Environment, Geneva, 2012.
- United Nations General Assembly. (2015). Transforming our world: the 2030 Agenda for Sustainable Development (Resolution A/RES/70/1). https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf.
- Van Bergeijk, P.A., van der Hoeve, R. (Eds.), 2017. Sustainable Development Goals and Income Inequality. Edward Elgar Publishing.
- Vereshchagina, A., Gnatyuk, M., Pechkurov, I.Y.V.E., Kulikov, S., Osipova, N., 2018. Social inertia as a destructive factor in the development of the innovative economic system in the Russian Federation. *J. Appl. Econ. Sci.* 13 (5).
- Wang, D., Hou, Y., Li, X., Xu, Y., 2022. Developing a functional index to dynamically examine the spatio-temporal disparities of China's inclusive green growth. *Ecol. Indic.* 139, 108861. <https://doi.org/10.1016/j.ecolind.2022.108861>.
- Wendling, Z.A., Jacob, M., Esty, D.C., Emerson, J.W., 2022. Explaining environmental performance: insights for progress on sustainability. *Environ. Dev.* 44, 100741.
- World Bank. (2019). World development indicators. Online. <https://databank.worldbank.org/source/world-development-indicators>. Accessed 03/06/2019.
- World Bank. (2018). "Strong but not broadly shared growth" Mozambique, poverty assessment. Poverty and equity global practice Africa Region. <http://documents.worldbank.org/curated/en/248561541165040969/pdf/Mozambique-Poverty-Assessment-Strong-But-Not-Broadly-Shared-Growth.pdf>.