Journal of Cleaner Production 383 (2023) 135266

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Overcoming poverty traps in Mozambique: Quantifying inequalities among economic, social and environmental capitals

Biagio F. Giannetti [a,*], Estêvão S. Langa [a], Cecília M.V.B. Almeida [a], Feni Agostinho [a], Geraldo C. de Oliveira Neto [b], Ginevra Virginia Lombardi [c]

[a] Post-graduation Program on Production Engineering, Paulista University, Brazil
[b] Business Administration and Industrial Engineering Post-Graduation Program, FEI University, Tamandaré Street, 688 – 5 Floor, zip code: 01525-000 - Liberdade, Sao Paulo, Brazil
[c] Dipartimento di Scienze per l'Economia e l'Impresa, University of Florence, Italy

ARTICLE INFO

Handling Editor: Zhifu Mi

Keywords:
Emergy
5SEnSU model
Poverty
SDGs

ABSTRACT

Assessing sustainable development strategies and alternatives depends on placing human well-being and the environment at the core of policy efforts and developing accounting methods to determine whether countries are progressing towards increasingly equal well-being. In this work, emergy accounting was used within the five-sector sustainability model (5SenSu) for measuring resource use inequality. As a diagnostic proposal, the 5SEnSU model based on the theory of ecologically unequal exchanges and emergy synthesis were used to assess Mozambique's poverty traps. Inequalities were measured considering the flows of goods, energy, and money between the social, economic, and environmental sectors as representative of the national economy. The 5SEnSU model showed that the environment directly supports a large part of the Mozambican population and that the country has growth potential according to the natural environment over 38 sej/sej, which must be used to ensure sustainable and equitable growth. Mozambique also has the potential (23:1 in emergy units) to maintain carbon neutrality and preserve forests and soil resources while undergoing economic development and growth. Mozambique has carbon credit and a resource surplus but needs to develop mechanisms to improve economic sectors through cleaner and well-being-centered development policies. High inequality between the social sectors and the economic system exposed a high dependency on local environmental resources characterizing a condition of vulnerability. The reduction in the number of people living below the poverty line and the effective implementation of the sustainable development goals may be achieved by balancing the capacity of the economic system with the country's environmental/social capacitiy.

1. Introduction

Africa is the most unequal region in the world (ADB, 2015), a condition persisting over time regardless of the differences among African countries in terms of development level and resource endowment. The continent includes 33 of the 47 least-developed countries in the world (UNCTAD, 2018; 2019b). The reduction of inequality and poverty has been a central goal in all the international Sustainable Development Agendas (Lakner et al., 2019), from the United Nations Millennium Declaration and the Millennium Development Goals (UN, 2015a) to the Agenda 2030 and the Sustainable Development Goals (SDGs) (UN, 2015b). While refers explicitly SDG 10 specifically refers to reducing inequalities, understanding why and how they occur in Africa is essential for reaching other targets such as SDG 1, no poverty (Odusola et al., 2017). The United Nations Conference on Trade and Development (UNCTAD, 2018) recognized the longstanding marginalization of the least-developed countries and the increasing inequalities among them, calling for the need for international support. The battle against poverty and regional inequality is a priority on the public policy agenda of several countries, a major activity of many economic and political institutions, and the subject of extensive research (Fosu, 2009, 2017; Barbier, 2005, 2012; Nel, 2008, 2018).

Measuring inequality requires decisions on variables, study population, and distributional characteristics of interest. According McGregor

* Corresponding author. Universidade Paulista (UNIP), Programa de pós-graduação em Engenharia de Produção, Rua Dr. Bacelar 1212, 4° andar, CEP 040026-002, São Paulo, Brazil.
E-mail address: biafgian@unip.br (B.F. Giannetti).

https://doi.org/10.1016/j.jclepro.2022.135266
Received 8 September 2022; Received in revised form 18 November 2022; Accepted 20 November 2022
Available online 25 November 2022
0959-6526/

et al. (2019), these decisions should be closely linked to an underlying objective defined by the social welfare function. Inequality is typically related to wealth or income, and its measure is affected by political, economic and social interests that often determine the chosen variables. Poverty has multiple definitions and can be assessed through different parameters. Opschoor (2007) defined poverty as the social condition of chronic insecurity resulting from the malfunctioning of economic, ecological, cultural and social systems. This condition leads groups of people to lose the ability to adapt, survive and live beyond minimum levels of satisfaction with their needs and aspirations. For Reed (2002), poverty results from people's inability to access life-sustaining assets, including environmental and cultural assets. To understand and quantify the interdependence of the objectives of reducing poverty and inequality, Lakner et al. (2019) performed a set of scenario simulations for global poverty from 2018 to 2030. Using different assumptions about growth incidence curves to model changes, they suggested that reducing each country's Gini index (a well-known and broadly used measure of inequality in income distribution) by 1% per year would have a greater impact on global poverty than increasing each country's annual growth by 1% above forecasts, which shows the central role of inequality in the elimination of extreme poverty.

Different degrees of inequality can lead to substantial disparities not only between countries but also within each country in Sub-Saharan Africa (Fosu, 2009, 2017) because the income-growth elasticity of poverty does not only depend on the initial level of inequality, it is also dependent on the average income relative to the poverty line of each country. The structure of economic relations among countries is a critical factor for national and global inequality. More than two-thirds of global inequality can be explained by differences in income between countries, and only one-third by distribution patterns within countries (Wess, 2013). Overall, inequalities between countries are shaped and reinforced by the nature of the international economic system and the structures that govern these relations (Melamed and Samman, 2013; Doyl and Stiglitz, 2014). According to neoclassical theories of regional growth, disparities between regions should not persist over time as convergence naturally occurs through the free market (Ray, 2007; Wijerathna et al., 2014). Based on this thought, the drivers of convergence might be attributed to the movement of production factors (favoring developed regions over lagging regions) among the regions in search of greater economic returns or new technology uptake. As evidenced by (UNEP - United Nations Environment Programme, 2016), UNCTDA (2019) and Dorninger et al. (2021), regions that produce primary products are generally poor, with a vulnerable population highly dependent on commodity production and without access to the market. These regions produce valuable environmental products that, in the end, do not benefit the producing region, serving only as a source of raw material for the metropolises.

The mechanism of reinforcing inequality that causes persisting poverty is known as the poverty trap (Azariadis and Stachurski, 2005), and occurs at different levels that may reinforce each other, posing extra-difficulties in dealing with poverty alleviation (Radosavljevic et al., 2021). The concept of poverty traps helps explaining inequality between as well as within countries (Easterly, 2001; Barrett and Swallow, 2003). Measuring inequality is thus a necessity not only to assess and monitor its very own dimensions but also to set goals to overcome poverty traps. Among similar other countries in Africa that are facing inequalities, the evolution of poverty in Mozambique resulted in notable regional disparities, with almost one in two Mozambicans trapped in chronic poverty and about 25% of the population considered highly vulnerable (World Bank, 2018) - measured with reference to the international poverty line (US$2.15 per person per day in 2017 PPP), poverty in Mozambique reduced from 79.8% in 2002 to 69.6% in 2008 and to 64.6% in 2014. Between 2020 and 2021, poverty in the country reached an average of 64% and is estimated to continue at that level in 2022 (World Bank, 2022). Mozambique shows the lowest human development index (HDI of 0.446) among the southern African countries (World Bank, 2018; ADB, 2015) and has been the subject of many studies on poverty and inequality (Arndt et al., 2010, 2012; Giesbert and Schindler, 2012; Akobeng, 2016; Alkire et al., 2017; Gradín and Tarp, 2019). Lavopa and Szirmai (2018) identified Mozambique as a typical example of a country that has been in a poverty trap for decades (1991–2014) with low labor force productivity. According to the World African Development Bank (2018), the poverty rate in Mozambique decreased from 60% in 2002/2003 to 48% in 2015, household consumption growth was accelerated after 2008. Still, the economy became less inclusive, disproportionately benefiting the more fortunate. This indicates a more general trend of fast reduction in poverty and increasing interregional inequality in some regions where poverty has historically been the highest.

Studies on poverty and inequality in Mozambique mostly focused on income distribution. There is a need for evaluations that also consider the degree of inequalities allied to access environmental resources (Nel, 2008; Barbier, 2012; Doyl and Stiglitz, 2014). According to UNEP 2012, countries should assess their state of development not only through measures such as the HDI and economic growth but also in terms of the degree to which their total use of resources is derived from the environment. Frugoli et al. (2015) confirmed that the lack of correlations with the fraction of renewable resources for all groups of social, economic, and environmental indicators considered confirmed the well-known criticism that the HDI disregards environmental issues. From the indicators considered, the HDI is reasonably satisfactory when combining economic and social aspects, with a strong inverse correlation with the biophysical indices.

The HDI was introduced in the 1990s (UNDP, 2019) as an essential step towards a measure of progress defined less by GDP growth and more by social targets (Biggeri and Mauro, 2018). Regarding this index, Hickel (2020) highlighted that the limitations of the HDI became visible in the 21st century due to the growing debate on climate change and ecological collapse. The HDI does not value ecology issues and maintains an emphasis on high levels of income (UNDP, 2011) which, given the strong correlations between income and ecological impact, violate sustainability principles (Hickel, 2020). The HDI is relatively crude because it does not consider sustainability, vulnerability, and inequality, among others (Chhibber, 2020). In rankings on the level of development, countries at the top of the HDI have been those that use more carbon and deplete more natural resources than those below them (Chhibber, 2020; UNDP, 2019). Mozambique is a country endowed with diverse and abundant natural resources with a high potential to boost the country's development. Even with abundant resources, Mozambique remains the poorest country in Southern Africa. It ranks among the 10 least developed countries in the world, with around 54% of the population needy and very dependent on the environment for subsistence. This results in environmental degradation and high pressure on the environment (MICOA, 2014). While poverty alleviation does not directly reduce environmental pressures, it largely enables the implementation of necessary actions to deal with environmental impacts (Markandya, 2001). For example, the Government of Mozambique implemented the Environmental Poverty Initiative (PEI) developed by the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) to integrate environmental issues and their indicators into national development plans (UNDP-UNEP PEI., 2015).

In this context, a novel approach for measuring inequalities is proposed in this work focusing on the balance of resource flows (including energy, goods, services and currency) between the human systems, economic activities, and the environment. This approach is supported by the theory of ecologically unequal exchange rooted in the world-system theory of unequal economic exchange and dependence (Emmanuel, 1972; Prebish, 1950), which assumes the existence of interdependence in the development of regions and not as a system regionally isolated from the global. Therefore, central regions depend on foreign natural resources to fuel their socioeconomic metabolism (Piñero et al., 2020) with environmental costs shifting to peripheral (poor) regions. To maintain a holistic perspective, the approach of the present is not based on estimations of human preferences, such as in utility theory or methods such as “willingness to pay”, but it models inequalities through “losses” and “gains” under a biophysical perspective. The interactions among capitals are evaluated from the standpoint of the five-sector sustainability model (5 SEnSU; Giannetti et al., 2019), suitable to represent an economic system and its manifold interactions with society and the environment. To account for the very different nature of flows between sectors, the emergy synthesis method was used. This method considers all the different resources and energy (including natural resources and human work) necessary to make a specific product or service (Odum, 1996; Campbell, 2009). The uneven geographical distribution of energy and other natural resources suggests that exchanges between nations and economic sectors, for example, are necessary and can contribute to more efficient and productive use in general (Jorgenson and Rice, 2012).

Bearing in mind that international monetary relations are built on a hierarchy between currencies that generate Core-Periphery structural imbalances, thus preventing the attraction of long-term investments for ecological transition (Svartzman and Althouse, 2022), it is essential not to ignore the fact that monetary dominance between sectors, countries and/or regions depends on the continuous and uneven flow of resources from the periphery to the centers that generate environmental resources. This research contributes to the discussion on the mechanisms that reinforce inequalities (which, for this study, we can call the ecological poverty trap), specifically in the case of Mozambique, by demonstrating that the eradication of poverty can only be possible when considering the relationship of scarcity of biophysical resources that potentially surpass the single use of the HDI and economic aspects to measure inequalities when proposing alternative ways to achieve sustainable development.

The “ecological poverty trap” according to Wackernagel et al. (2021) is the situation in which the growing number of the population lives in countries with biocapacity deficits and below-average income, where income tends to frustrate the ability of economies to compete for necessary resources in the global market and eliminates the chances of eradicating poverty. Therefore, to sustain progress and eradicate poverty, countries need to meet two conditions (Global Footprint Network, 2021): sufficient natural resources to match their Ecological Footprint (enough natural resources to provide food, fiber, building materials, and sequestration of enough CO_2, among other factors), or money to competitively buy what they need in the foreign market. An ecological poverty trap leaves households vulnerable to external disturbances (short-term and long-term risks) posed by climate change, droughts, natural disasters, threats, and other environmental risks, disproportionately affecting developing economies (Barbier and Hochard, 2019). A country tends to fall into an ecological poverty trap when it is characterized by low environmental quality, low life expectancy, and, therefore, low physical capital per capita (Dao and Edenhofer, 2018).

The main principles of the theory of ecologically unequal exchanges apparent in the literature are: Relations of unequal exchanges of resources, ecological interdependencies, and unequal power in the zones of the world economy create and reproduce multiple forms of inequality in the world system (Frey et al., 2018; Dorninger et al., 2021; Jorgenson and Rice, 2012). The inequalities of ecologically unequal exchanges create an apparent contradiction of excessive consumption of resources, but with relatively less environmental degradation in regions where environmental resources are exploited, while under-consumption of resources in the periphery leaves most resident populations with precarious living and health standards, inadequate income, and degraded ecosystems (Frey et al., 2018; Jorgenson and Rice, 2012).

The present research is based on the theory of unequal ecological exchanges that rests on the idea of world systems and human ecology and focuses on analytical attention in examining the appropriation, use, and flows of resources and the physical and monetary balances of loss resulting from this use of these resources, in addition to accounting in some way for the environmental impacts of this flow and use of resources.

2. Methods

This study uses data on the production of goods from all productive sectors in Mozambique, including data on foreign trade exchanges (exports and imports of goods) for the year 2014; the services sector (i.e., health, education, and others) are not included in this study. Data were mainly obtained from databases of the National Statistics Office (INE) and Ministry of Economy and Finance (MEF) of Mozambique (2013–2014); when other data sources are used, their complete reference is provided. The choice of 2014 as the basis is due to the data availability, but the same procedure can be applied when more updated data becomes available.

Ecological poverty traps, or the mechanisms that reinforce inequalities, it is understood in this work as the potential existing inequalities among capital flows. In other words, the environment, economic and social capital should work in a balanced way, each one understanding the growth limits of another to avoid the inequalities as often found in those less developed countries. The present study empirically evaluates how Mozambique can overcome ecological poverty traps. For this goal, it is used the theory of ecologically unequal exchanges (Emmanuel, 1972; Prebish, 1950), the emergy synthesis (Odum, 1996), and the 5SEnSU model (Giannetti et al., 2019) to evaluate the use, resource flows, and the physical and monetary balances in addition to the balance of gains and losses between sectors of the Mozambican economy. The study assumes that the sectors of the 5SEnSU model proposed by Giannetti et al. (2019) are the hypothetical composition of sectors of the Mozambican economy. For the analysis, indicators such as emergy flow, forest and soil loss, energy and renewable resources, forest area needed to absorb CO_2, forest area, labor, wages, household consumption in monetary terms, and resources were considered consumed imports, and exports in monetary terms and terms of imported and exported resources. Based on these indicators and each indicator for its respective sector, the Physical Exchange Ratio Balance, which provides a measure of direct and relative exchange of materials between sectors, and the Terms of Exchange, which informs the average monetary value, were calculated relationships according to established relationships, per unit of mass flow of goods between the sectors of the 5SEnSU Model. The same analysis has already been used in studies that have included indirect (incorporated), and direct trade flows in several countries (Infante-Amate and Krausmann, 2019; Dorninger and Hornborg, 2015; Fischer-Kowalski et al., 2011). Therefore, the emergy relationships between sectors 1 and 3 were studied: use and loss of environmental resources, emergy relationships between sectors 3 and 4: work and wages, emergy relationships between sectors 3 and 5: consumption and spending by families and emergy imported and exported by sector 3 to the world. From this perspective, a useful tool for assessing the relationship among capitals is the 5SEnSU conceptual model of sustainability, as explained in the next section.

2.1. Modeling proposal in assessing poverty traps

Fig. 1 represents the general model of 5SenSu that shows the trade-offs among environmental, economic, and social capitals acting as providers and/or receivers of energy, material, money, and information. According to Giannetti et al. (2019), the 5SEnSU is a model aligned with many other input-state-output sustainability models, and its design is based on the three Daly’s (1990) fundamental axioms, but also includes a fourth axiom that considers the societal interactions with the whole system (in d): (a) No resource should be used at a rate higher than its generation rate; (b) No contaminant must be produced at a higher rate than recyclable, neutralized or absorbed by the environment; (c) No non-renewable resource should be used faster than the time required to

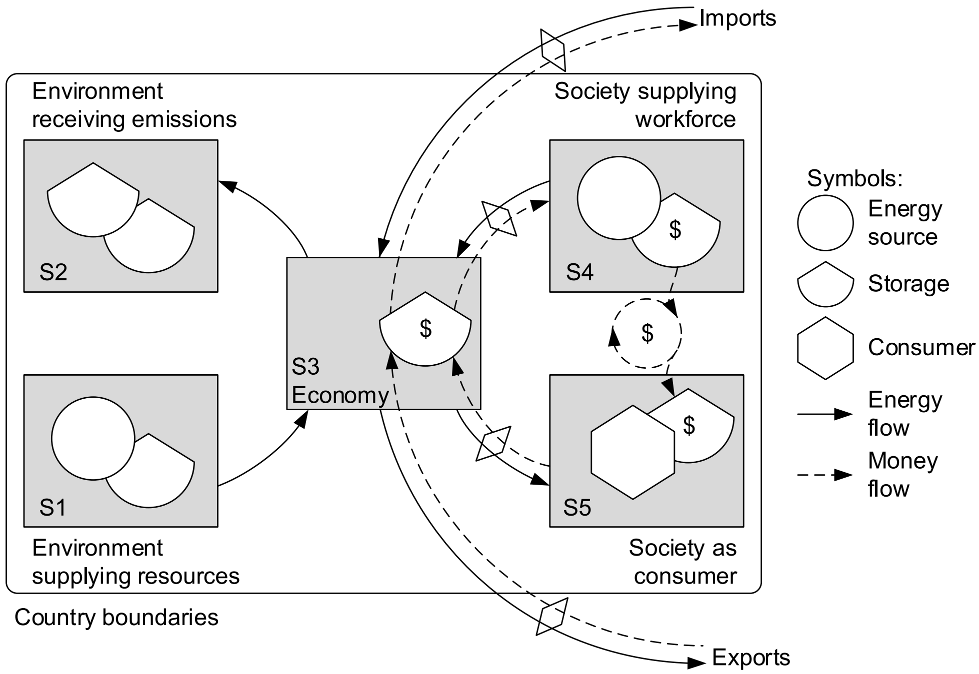

Fig. 1. General model of 5SEnSU with the addition of imports and exports flows. Adapted from Giannetti et al. (2019). S = sector.

replace it with a renewable resource, therefore, there must be a balance between the environment as a resource provider and as a recipient of waste and pollutants (the production of goods and services must be limited to the restrictions imposed by the sustainable exploitation of natural resources and the responsible consumption of society, which guarantees their sustainability); (d) For humans as social beings, their relationship as a supplier and recipient of labor, products and services in the economic sector must be fair and beneficial.

The 5SenSu model is been used in different fields, including transportation sector (Agostinho et al., 2019), the assessment of water & wastewater treatment companies (Giannetti et al., 2022a), to assess the relationship between circular economy and sustainability of economies (Terra et al., 2022), to discuss about the importance of environmental, social and governance label for companies (Giannetti et al., 2022b), and the production of rice in different countries (Moreno Garcia et al., 2021). The original 5SEnSU model is slightly modified here to allow the evaluation of mechanisms that reinforce inequalities among capitals. The exchanges of exported and imported goods were added to better reflect their relations with the sectors and explain how Mozambique's economy works. The model allows access flows of resources and/or waste across the sectors broadly. In particular, the environment is considered a supplier of resources (S1) to the public and private economic sectors (S3) and a recipient of waste and emissions (S2) from S3. Similarly, society is considered a workforce provider (S4) and a service/product recipient (S5) to or from S3.

Different indicators can be used to track the flows among sectors. Most of the indicators considered in this work derive from emergy accounting since this method allows to conversion of any flow of goods, services, energy, currency, and information into a common unit (expressed in solar emergy joules, sej). According to previous specific literature, including Giannetti et al. (2013), Morandi et al. (2015), and NEAD (2020), among others, this method has been widely used in the scientific literature, including assessment of countries and regions. Emergy includes the "real" effort from nature required to obtain the final product from diluted forms of energy (e.g., solar energy; Odum, 1996). Instead of using the traditional socioeconomic indicators that are usually based on subjective approaches in establishing value, we advocate that all characteristics behind the emergy method allow it to support discussions about the mechanisms that reinforce inequalities under a more holistic and objective approach.

Initially, the 5SEnSU model allowed the choice of indicators by the analyst to better represent the system under study and support discussions on the initial established objectives. Still, the meaning and scope of each sector must always be respected. Specifically, for this work that aims to assess the mechanisms that reinforce inequalities (or poverty traps) in Mozambique, the chosen emergy-based values are presented in the next sections in detail. It is important to highlight that this study focuses on issues related to inequality in terms of resource use since it is well known that biophysical resources (an ecocentrism perspective) represent the real wealth sustaining the development of society, usually named as strong development or even strong sustainability. Thus, all other forms of inequality, such as those based explicitly on income and/or market opportunities, are outside this study's scope.

2.1.1. Emergy exchanges between the environment as a provider (S1) and the economy (S3)

The environment provides free-of-market resources (such as solar radiation, water, wood, soil, etc.) to be used by the public and private economic sectors. The efficient use of natural resources while conserving the capacity of the environment to re-generate them is a requirement for sustainability under a biophysical lens. There is no currency exchange between the environment and the economic sector, although it is well known that natural resources are the basis of economies' wealth. Hereupon, the flows of renewable and non-renewable resources supporting Mozambique's economy were considered representative of the emergy exchanges between S1 and S3 in the 5SEnSU model. The emergy of renewable resources and the emergy loss with soil and forest were considered indicators. While renewable flows support a more sustainable growth, the non-renewable ones act as drains of emergy from Mozambique's natural capital, reducing its ability to withdraw higher rates of renewable resources over years.

2.1.2. Emergy exchanges between the environment as a receiver (S2) and the economy (S3)

The principle of carbon neutrality is one of the key concepts when discussing sustainability. Greenhouse gas emissions should be maintained at the same or lower levels of the absorption capacity of forests and other ecosystems in the country. Understanding this vital service made by nature, emergy values of forestland in Mozambique over the emergy of forest extension needed to absorb CO_2 emissions from agriculture and industry are considered as indicators representing the emergy exchanges between S2 and S3 in the 5SEnSU model.

2.1.3. Emergy exchanges between the economy (S3) with imports and exports of goods and services

In this work, the word economy is considered a general label that embraces public and private economic sectors. International trade is often assessed through the so-called terms of trade, i.e., the relationship between export and import prices, or through the purchasing power of exports, i.e. the amount of imports those exports can buy, representing the interdependence of the goods markets (Spatafora and Irina, 2009). However, emergy accounting provides a broader and more holistic perspective of international trade by considering the environmental and human effort embodied in the traded goods (Campbell, 2009). In particular, the emergy to money ratio (EMR) indicator, defined as the ratio of total emergy demanded by a country over its gross domestic product (GDP), is an indicator of the overall amount of energy and resources invested in a country to return 1 USD value (Odum, 1996). To account for the 'real value' of goods (under a biophysical perspective) traded in international markets, emergy flows are accounted for in two different ways: (i) physical flows of energy and matter due to imported and exported goods; (ii) monetary flows due to importation and/or exportation goods. While the former is calculated by considering all goods and their transformities (a coefficient factor from the emergy method that reflects energy quality and global efficiency), the later considers the EMR to convert money into emergy flows. The monetary value of imported goods in Mozambique (in USD) was converted into emergy values using Mozambique's EMR in 2014 (3.14 E+13 sej/USD, Table SM D.1. at Supplementary Material). Similarly, the emergy value of exports was obtained by multiplying exports' monetary values by the EMR average value for the world economy (EMR of 2.67 E+12 sej/USD; Table SM E.3. at Supplementary Material). EMRs are different because while the former represents the emergy-economy performance of Mozambique, the later represents the purchasing power of those countries that imports goods from Mozambique.

Additionally, the assessment of international trade is made by the emergy exchange ratio (EER) index, expressed by the ratio between the emergy received and the emergy delivered in any economic transaction (Odum, 1996). The EER is commonly used to establish comparisons in trade between countries. In this relationship, the trading partner receiving more emergy receives the greatest real wealth, and the highest stimulus pushes it. When EERs approximate 1, it is a signal of more balanced international trade dynamics (Giannetti et al., 2013; Geng et al., 2017; Tian et al., 2018). Procedures for calculating EER are shown in Fig. 2, where flows are firstly expressed in emergy values. Then, their ratio is considered a measure of one side relative advantage over the other (Odum, 1996).

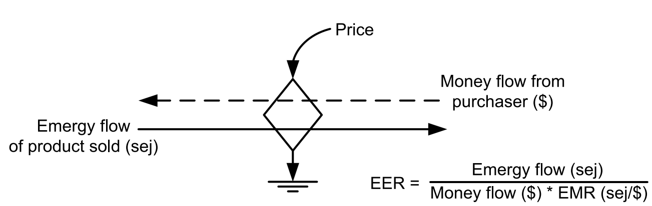

Fig. 2. Emergy flows in a purchase process. Source: Adapted from Odum (1996). Legend: Emergy exchange ratio (EER) index; Emergy per money ratio (EMR) of the purchaser.

2.1.4. Emergy exchanges between the workforce supplied by society (S4) and the economy (S3)

The society represents an important resource for the public and private economic sectors in terms of workforce. The search for equity between the contribution of human labor and its reward reduces inequality between the productive sector and society as a supplier of the workforce. This exchange can be estimated by the ratio between the emergy value of salaries and/or wages received by Mozambique's population, with the emergy delivered as human labor.

2.1.5. Emergy exchanges between the society as a consumer (S5) and the economy (S3)

The ultimate goal of a nation's economy is - or should be - to maximize the well-being of its population. The society receives goods and services from the economic sector that are fundamental for sustainable human development. Once determining whether goods and services are fairly priced is fundamental to an equitable economy, the ratio between emergy values of household consumption goods by the emergy value of household consumption expenditures was used to assess the balance between society and the economy.

3. Results

The 5SEnSU model of Fig. 3 allows for assessing poverty traps through the existing trade-offs among Mozambique's environmental, economic and social capitals. All flows are quantified in emergy units (sej/yr) to allow direct comparisons, considering the quality of resources from a biophysical perspective. Two emergy flows are calculated for each sector of the 5SEnSU model to balance the total amount of indicators. This is important because equality may occur when a balance among all three capitals is achieved, which can also support discussions on the country's sustainability. Based on the numbers provided by Fig. 3, emergy flows are presented in pairs of sectors to allow a better understanding.

3.1. Emergy exchange between sectors 1 and 3: use and loss of environmental resources

The environment provided renewable resources for the economic sector amounting to 2.98 E+23 sej/year in 2014, while the non-renewable emergy lost as forest land and soil loss amounted to 7.93 E+21 sej/year (Fig. 4). A credit of 2.90 E+23 sej/year indicates that Sector 3 causes forest and soil loss to occur in lower rates than the use of renewable sources.

3.1.1. Emergy exchange between sectors 2 and 3: forest area and carbon sequestration

The difference between the emergy of the forest area in Mozambique in 2014 and the emergy of the forest area required to capture CO_2 from its economic activities amounts to 4.68 E+22 sej/yr (Fig. 5). This result indicates that Mozambique has an emergy carbon credit as its forests exceeds, by a factor of 23, the forest extension needed to capture annual CO_2 emissions from the country's economic activities.

3.2. Emergy exchange between sectors 3 and 4: labor and wages

According to the World African Development Bank (2018), household consumption in Mozambique is 70% represented by non-market environmental goods that provide the means of subsistence for the local population. On the other hand, only 30% of household consumption is represented by goods and services from the public and private economic sector sectors (see Table SMC at Supplementary Material for further details on the calculation methods). Fig. 6 shows that wages provide households with purchasing power higher than the emergy, goods, and services consumed by society. The difference between emergy in wages and labor in Mozambique in 2014 returns a positive

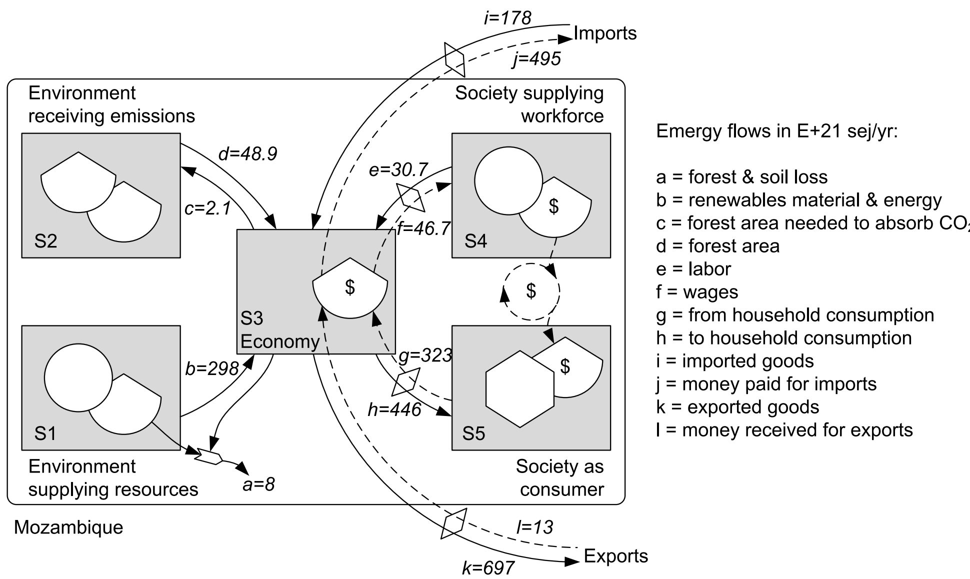

Fig. 3. The five sectors sustainability model (5SEnSU) applied to Mozambique, 2014. S = sector.

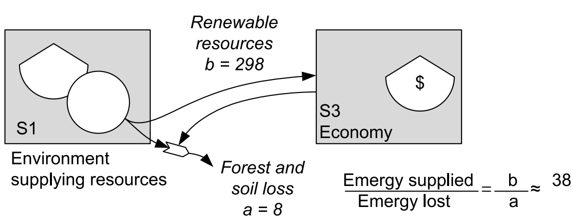

Fig. 4. Renewable emergy supporting 2014 Mozambique's economic development and the emergy drained due to forest and soil loss. Emergy flows in E+21 sej/yr. Calculation details are in Table SM A at Supplementary Material.

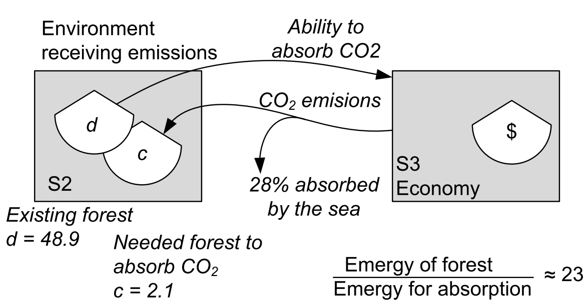

Fig. 5. Forest areas absorbing the CO_2 released by Mozambique's economic sector, 2014. Emergy flows in E+21 sej/yr. Calculation details are in Table SM B at Supplementary Material.

value of 1.60 E+22 sej, indicating a 1.52 times benefit for people receiving wages. However, it is important to emphasize that working conditions and quality of work are disregarded from this analysis.

It can also be observed a difference in the ratio of emergy in wages and labor when separating formal and informal economy. In particular, while social benefit from work seems very high for the formal sector with a ratio of emergy in wages to labor equal to 15.64, for the informal sector, it appears that society does not receive benefits because it loses 0.32 benefits (purchasing power), with a wage to labor ratio of 0.68.

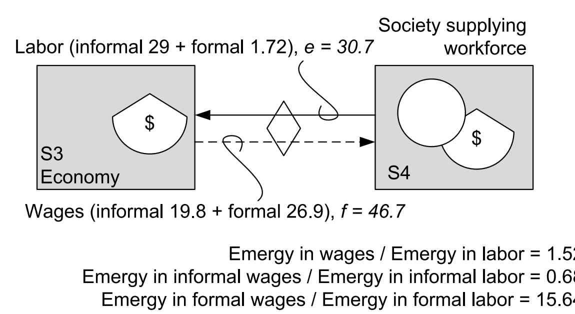

Fig. 6. Emergy of labor and its counterpart in wages for Mozambique, 2014. Emergy flows in E+21 sej/yr. Calculation details in SMC.

3.3. Emergy exchange between sectors 3 and 5: household consumption and expenditures

Considering that goods and services represent 16% of household consumption from the public and private economic sectors, we have considered the emergy of 16% of household savings and household expenditures; 16% of the total emergy demanded (446 E+21 sej/yr) resulted in emergy from the economy of 71.4 E+21 sej/yr. The ratio (0.22) indicates a loss of purchasing power favoring the economic sector. The results are in line with that advocated by the World African Development Bank (2018), according to which families in Mozambique not only depend on goods received from the economy but also depend on more than 70% of free resources for their survival, resulting in a negative value of −2.52 E+23 sej/year in this trade (Fig. 7).

3.4. Emergy imported and exported by sector 3

International trade is an important factor in promoting development between nations. A country's trade balance measures the cash surplus or deficit of a country. Still, it does not represent the real effort to produce resources or generate money for a national economy. The higher the EMR of a country, the more competitive it will be in attracting investments as foreign direct investment since a dollar spent in that

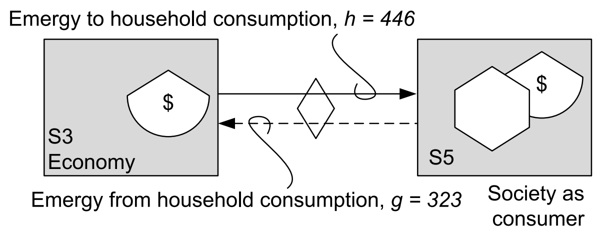

Fig. 7. Emergy flows of household consumption and expenditures for goods and services in Mozambique (2014). Emergy flows in E+21 sej/yr. Calculation details are in Tables SM D at Supplementary Material.

country can purchase a larger amount of environmental resources than in countries with lower EMR (in general, developed countries; Sevegnani et al., 2017). The EMR of Mozambique in 2014 was 3.90 E+13 sej/USD, higher than the world economy EMR of 2.67 E+12 sej/USD, indicating that the national economy of Mozambique requires much effort, in terms of energy, resource, and services, to generate a dollar as compared to its trade partners in international markets.

In 2014, Mozambique paid a total of 1.27 E+10 USD for imports, corresponding to an emergy value of 3.99 E+23 sej, considering the national EMR for the same year. This emergy value is, however, smaller than the emergy value embodied in imported goods (6.99 E+22 sej), indicating an unfavorable (or unequal) trade in the import market (Fig. 8). In other words, Mozambique received goods and services produced with lesser effort than the money counterpart paid for it. In 2014, Mozambique received payments corresponding to 1.28 E+22 sej, calculated using the world economy EMR of 2.67 E+12 sej/USD. Still, at the same time, the emergy value of the goods exported amounted to 59.9 E+22 sej.

The emergy value of the monetary counterpart to imports and exports and the emergy value of imported and exported products can be used to calculate a series of emergy exchange ratios that provide a measure of the real effort in producing and exchanging goods (Table 1). Assessing this real effort is important to guide policies to reduce inequalities generated through international trades. In general, Mozambique delivers 5.7 times more emergy during import transactions and 46 more emergy during export transactions, highlighting the existence of an unbalanced trade in emergy units.

4. Discussions

Fig. 3 shows the current result of emergy flows and highlights the inequalities between the three selected capitals, which may lead to negative consequences for the development of Mozambique. Inequalities can result from the lack of opportunities for society's development (WESS, 2013), economic instability, investment reduction and/or the implementation of distorted policies that produce a concentration of power in a small portion of the population (World Bank, 2018). Although there is a record of improvement in the average indicators of family wealth in Mozambique, the country has been registering an increase in inequalities between 1997 and 2017, with evidence indicating that the southern provinces are experiencing equitable development (Santos et al., 2021). The Mozambican society receives net benefits (from 23 to 38 times higher than the emergy costs) that are not generated by the economic sector but are the outcomes of agricultural and artisanal mining activities, which, together with extraction activities, are destined for the economic sector.

Table 1
Different emergy exchange ratios (EER) for Mozambique's international trades, 2014.

Description	EER
Emergy in monetary counterpart to imports/Emergy in imported goods and services	5.7
Emergy in exported goods and services/Emergy in monetary counterpart to exports	46.1
Emergy in monetary counterpart to imports/Emergy in monetary counterpart to exports	30.7
Emergy in exported goods and services/Emergy in imported goods and services	8.6

Although the loss of forest and soil occurs at lower rates than the use of renewable resources, this favorable balance of 38/1 should be carefully considered since Mozambique is a developing country and, as such, experiences increasing growth with larger pressure on natural resource stocks (UNDP-UNEP PEI., 2015). The expansion of land for mineral extraction and agricultural activities has an increasing trend for the coming years that may result in a considerable loss of forests, wetlands, and other natural habitats. As this loss is mainly characterized by burning natural vegetation, this land tends to exhibit low productivity for intensive agriculture (MITADER, 2018). According with the same report, alternatively and its effort on the part of farmers or government bodies is still incipient to highlight the development of research at the country level. Also, improve agricultural productivity and exploitation of biodiversity or natural resources in all aspects of the particular field of environmental sciences. As the natural capital represents the real wealth of a nation, economic, political, and scientific efforts in reinforcing the productivity and maintenance of the natural capital of Mozambique are of paramount importance.

Mozambique emits 0.1 tons of CO_2 per capita per year, less than the average emissions per capita in low-income countries (~0.3 tons; ADB, 2018), but it is important to emphasize that Mozambique's carbon credits have been steadily decreasing since 1960 (Global Footprint Network, 2022). Many emissions in Mozambique comes from forest burning for agricultural practices. This indicates that the expansion of productive sectors is accompanied by a reduction of forest areas, with a consequent increase in emissions and a decrease of absorption capacity. Strategies for converting these activities into market-value activities for vulnerable populations and introducing public policies to promote development through activities connecting rural areas and urban centers would bring considerable benefits in terms of employment. In this regard, Mozambique developed a series of strategies for National Climate Change Adaptation and Mitigation for 2013 to 2025, affecting the forestry sector and developing low-carbon agricultural practices, as well

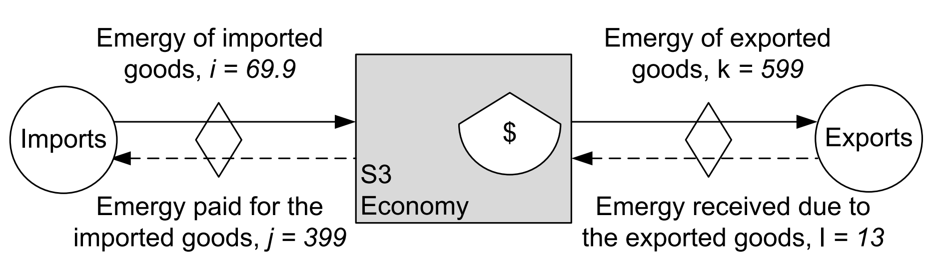

Fig. 8. Emergy of 2014 Mozambique's imports and their monetary counterpart. Emergy flows in E+21 sej/yr. Calculation details are in Tables SM E at Supplementary Material.

as plans for reducing deforestation and forest fires.

The current research results show a potential for growth and balance of natural capital with economic capital (S3). The trade-offs between Sector 3 and Sectors 1 and 2 show two sides of the same problem and make clear the need for efforts to encourage agricultural extension and research activities to develop specific knowledge to improve productivity and sustainable exploitation of natural and agricultural areas. The depletion of natural capital resulting from exploiting the same capital has been a common strategy of developing countries to promote economic growth, which poses a challenge to the exploration and efficient management of these resources. Losses of well-being due to environmental damage must be minimized and the income obtained from resource extraction after the internalization of externalities (Barbier, 2005, 2012) must be evaluated and compared in terms of real wealth (Odum, 1996). The investment in productive economic assets using the income resulting from natural capital depletion should be evaluated through the emergy approach that can measure the balance between sectors and estimate a resource use limit to generate economic wealth (Campbell, 2009).

For society as a provider of resources, it was observed that a social benefit comes from the formal sector (15.6 sej/sej). In comparison, there are no benefits for society (0.68 sej/sej) when labor comes from the informal sector. These results highlight a high level of inequality between formal and informal workers, which turns out particularly striking considering that the informal sector includes about 95% of the total labor force in Mozambique, according to the Danish Trade Union Development Agency (Ulandssekretariatet, 2014) and Balchin et al. (2017).

The difference between formal and informal wages to labor emergy ratios also indicates that households within the informal economy mostly depend on non-market environmental goods for subsistence (Campbell, 2009; Odum, 1996; World Bank, 2018). Households are depleting their savings, in emergy terms, since the purchasing power of the money used to buy goods is greater than the benefit families receive from consuming those goods.

In international trade, the results indicate that Mozambique is caught in a trap that forces it to export environmental products at low prices to pay for food imports at high values (5.7 times emergy in imports and 46 times in exports). The EERs obtained for Mozambique in 2014 are partially explained by the fact that the country mainly exports low-cost raw materials with high environmental load and imports highly processed and priced goods. This trade dynamics, in emergy terms, is observed for other rich-in-natural-resources countries, for example, Brazil (Giannetti et al., 2013), and seems to reflect the *raison d'ètre* of global markets. The difference between exports and imports in monetary terms indicates that Mozambique pays more money for imports than it receives for exports. In emergy terms, the difference between imports and exports suggests that the national economy's effort to pay for imported goods, by the national economy for paying to pay for imported goods, is much higher than that of the global economy to pay for exported goods from Mozambique.

Furthermore, the difference between the emergy value of imported and exported goods in Mozambique (−5.29 E+23 sej/year), without considering money flows, indicates that Mozambique exports more resources (directly and indirectly used for producing goods) than it imports. Therefore, Mozambique must establish policies to maintain its resource base obtain benefits in international trade, or at least stay in balance. However, the balance between partners should consider all aspects of their relationship, including factors that are difficult to assess, such as the exchange of technical and cultural information and the provision of security. What is fair in trade is also determined by the reserves and resource needs of the various states or regions and by the needs of the Nation to which they belong (Campbell, 2009).

4.1. Limitations of this study

Limitations of this study refer to the operationalization of the theory, method, data as well as the period of analysis. The ecologically unequal exchange theory hypothesis for this study was not tested for a time series, which opens space for future work in which the impacts of inequalities over time can be explored.

The 5SEnSU model was used to study the overcoming ecological poverty traps through ecologically unequal exchange relations and emergy synthesis. Therefore, although we have found interesting and useful results for public policy decision-making in favor of sustainable development in Mozambique, it does not imply that additional evaluation methods cannot be added to complement those of the 5SEnSU model. The 5SEnSU model simplifies and approximates the reality of key sectors of an economy aligned with the sustainability pillars proposed by the United Nations. The model can be considered appropriate for diagnostic purposes and hypotheses testing of a country's sectorial sustainable development policies.

The challenge posed by this work was to use emergy to facilitate comparisons, transforming monetary values of flows in terms of real wealth for comparison with emergy values. The availability of accurate wages and working-hours data was a challenge for this work. Expanding this study in a time series, including other countries of the SADC region would certainly provide even more robust results for more specific policies in these countries.

5. Conclusions

The quantification of the (im)balances across socio-economic sectors and the environment provided a broader perspective of the inequalities within Mozambique and on its international trade. The five-sector sustainability model showed that the environment directly supports a large section of the Mozambican population and that the country has potential for growth according to the natural environment 38 sej/sej surplus, which should be used to guarantee sustainable and equitable growth. Mozambique also has the potential (23:1 in emergy units) to maintain carbon neutrality and preserve forests and soil resources while going through development and economic growth. In this context, cleaner and well-being-centered development policies should guide the country towards equality in international markets and rescue households from informal jobs promoting formal employment and business models to improve the population purchasing power and reduce vulnerability, while reducing environmental impacts from deforestation and resource extraction.

Quantifying inequalities among economic, social, and environmental capitals allowed us to recognize that Mozambique, as several developing countries, is a resource-rich country with a weak economic system. Traps were identified in the interactions of the economic system with the environment and the society through the imbalances between sectors. If the imbalances are maintained, the country will remain in a poverty trap, overexploiting its natural resources without developing the economic system and promoting the well-being for the people. In the short and medium term, it is unlikely that Mozambique will escape from the traps it is caged or achieve a performance similar to that of its commercial partners. Achieving equality between countries may not be a feasible goal, as imports/exports flows do not depend only on one country choices – such as selecting international partners with similar Emergy Money Ratio to avoid losses in emergy - but on the complex structure of the international market. However, the country should strengthen key internal sectors of the economy and explore the current capacities seeking a favorable balance between the three dimensions of sustainability internally to meet the needs of its population. Fighting poverty and effectively implementing the SDGs will be difficult without balancing the capacity of the economic system with the country's environmental/social capacities.

Severe poverty reduction requires a systematic and comprehensive analysis of regional inequalities and the distorted distribution of valuable and scarce resources within and between nations. The five-sector sustainability model and emergy accounting provide a scientific basis to inform and monitor policy-making to promote environmental quality, societal well-being, and economic health.

Credit author statement

BFG: Research, writing and contextualization, revision. **ESL**: Research, writing and contextualization, revision. **CMVBA**: Research, writing and contextualization, revision. **FA**: Research, writing and contextualization, revision. **GCON**: Research, writing and contextualization, revision. **GVL**: Research, writing and contextualization, revision

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.

Data availability

Data will be made available on request.

Acknowledgements

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 for the financial support provided by CNPq Brazil (302592/2019–9).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2022.135266.

References

African Development Bank (ADB), 2018. Mozambique Country Strategy Paper 2018 -2022. Supporting Mozambique towards the High5s. RDGS June 2018. Available at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Boards-Documents/MOZAMBIQUE_-_CSP_2018-2022_Final_.pdf.
African Development Bank (ADB), 2015. Transition towards Green Growth in Mozambique: Policy Review and Recommendations for Action (Tunisia).
Agostinho, F., Silva, T.R., Almeida, C.M.V.B., Liu, G., Giannetti, B.F., 2019. Sustainability assessment procedure for operations and production processes (SUAPRO). Sci. Total Environ. 685, 1066-1018.
Akobeng, E., 2016. Out of inequality and poverty: evidence for the effectiveness of remittances in Sub-Saharan Africa. Q. Rev. Econ. Finance 60, 207–223.
Alkire, S., Roche, J.M., Vaz, A., 2017. Changes over time in multidimensional poverty: methodology and results for 34 countries. World Dev. 94, 232–249.
Arndt, C., Hussain, M.A., Jones, E.S., Nhate, V., Tarp, F., Thurlow, J., 2012. Explaining the evolution of poverty: the case of Mozambique. Am. J. Agric. Econ. 94 (4), 854–872.
Arndt, T.C., Jones, E.S., Tarp, F., 2010. Poverty and Wellbeing in Mozambique: Third National Poverty Assessment.
Azariadis, C., Stachurski, J., 2005. Poverty traps. In: Aghion, P., Durlauf, S. (Eds.), Handbook of Economic Growth, Vol. 1. Elsevier, Amsterdam.
Balchin, N., Coughlin, P., Papadavid, P., te Velde, D.W., Vrolijk, K., 2017. Economic transformation and job creation in Mozambique. In: ODI's Supporting Economic Transformation. SET), London, p. 97.
Barbier, E.B., Hochard, J.P., 2019. Poverty-environment traps. Environ. Resour. Econ. 74 (3), 1239–1271.
Barbier, E.B., 2005. Natural Resources and Economic Development. Cambridge University Press, Cambridge, 2005.
Barbier, E.B., 2012. Natural Capital, Ecological Scarcity and Rural Poverty (English). Policy Research Working Paper; No. WPS 6232. World Bank, Washington, DC. Available at: http://documents.worldbank.org/curated/en/277711468135304847/Natural-capital-ecological-scarcity-and-rural-poverty.
Barrett, C.B., Swallow, B.M., 2003. Fractal poverty traps, working paper, cornell university and world agroforestry centre. Available at: https://pdfs.semanticscholar.org/1433/1ea6fff90ab93ec5ed8db8f18febe70c362e.pdf. (Accessed 5 July 2019).
Biggeri, M., Mauro, V., 2018. Towards a more sustainable human development index: integrating the environment and freedom. Ecol. Indicat. 91, 220–231.
Campbell, D.E., 2009. Environmental Accounting Using Emergy: Evaluation of Minnesota. United States Environmental Protection Agency (EPA), Narragansett.
Chhibber, A., 2020. Measuring Human Development for the Anthropocene. UNDP Human Development Report Office, p. 54. Background Paper no. 3-2020. New York.
Daly, H.E., 1990. Toward some operational principles of sustainable development. Ecol. Econ. 2, 1–6.
Dao, N.T., Edenhofer, O., 2018. On the fiscal strategies of escaping poverty-environment traps towards sustainable growth. J. Macroecon. 55, 253–273.
Dorninger, C., Hornborg, A., Abson, D.J., Von Wehrden, H., Schaffartzik, A., Giljum, S., Wieland, H., 2021. Global patterns of ecologically unequal exchange: implications for sustainability in the 21st century. Ecol. Econ. 179, 106824.
Dorninger, C., Hornborg, A., 2015. Can EEMRIO analyses establish the occurrence of ecologically unequal exchange? Ecol. Econ. 119, 414–418.
Doyle, M.W., Stiglitz, J.E., 2014. Eliminating extreme inequality: a sustainable development goal, 2015–2030. Ethics Int. Aff. 28 (1), 5–13. Available at: https://www.carnegiecouncil.org/publications/journal/28_1/001/000002.
Easterly, W., 2001. The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics. MIT Press, Cambridge, MA.
Emmanuel, A., 1972. Unequal Exchange: A Study of the Imperialism. Monthly Review Press, New York.
Fischer-Kowalski, M., Krausmann, F., Giljum, S., Lutter, S., Mayer, A., Bringezu, S., Weisz, H., 2011. Methodology and indicators of economy-wide materialflow accounting. J. Ind. Ecol. 15 (6), 855–876.
Fosu, A.K., 2017. Growth, inequality, and poverty reduction in developing countries: recent global evidence. Res. Econ. 71 (2), 306–336.
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.
Frey, R.S., Gellert, P.K., Dahms, H.F., 2018. Ecologically Unequal Exchange: Environmental Injustice in Comparative and Historical Perspective. Springer.
Frugoli, P.A., Almeida, C.M.V.B., Agostinho, F., Giannetti, B.F., Huisingh, D., 2015. Can measures of well-being and progress help societies to achieve sustainable development? J. Clean. Prod. 90, 370–380.
Giannetti, B.F., Sevegnani, F., Garcia, R.R.M., Agostinho, F., Almeida, C.M.V.B., Coscieme, L., Genguyan, L., 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, 4126.
Giannetti, B.F., Scarpelin, J., Di Agustini, C.A., Paranhos, M.A.H.L., Lozano, P., Agostinho, F., Almeida, CMVB, 2022b. Perceived value versus real value: why can investros in sustainable companies fail in their mission? Cleaner Production Letters 3, 100020.
Geng, Y., Tian, X., Sarkis, J., Ulgiati, S., 2017. China-USA trade: indicators for equitable and environmentally balanced resource exchange. Ecol. Econ. 132, 245–254.
Giannetti, B.F., Demétrio, J.F.C., Bonilla, S.H., Agostinho, F., Almeida, C.M.V.B., 2013. Emergy diagnosis and reflections towards Brazilian sustainable development. Energy Pol. 63, 1002–1012.
Giannetti, B.F., Sevegnani, F., Almeida, C.M.V.B., Agostinhoa, F., Garcíab, R.R.M., Liu, G., 2019. Five sector sustainability model: a proposal for assessing sustainability of production systems. Ecol. Model. 2019 (406), 98–108. Available at: https://www.sciencedirect.com/science/article/pii/S0304380019302169.
Giesbert, L., Schindler, K., 2012. Assets, shocks, and poverty traps in rural Mozambique. World Dev. 40 (8), 1594–1609.
Global Footprint. Network, 2022. Mozambique - global footprint Network. Available at: https://data.footprintnetwork.org/?_ga=2.225236314.1594481002.1666427801-1490794690.1666427801#/countryTrends?type=BCtot,EFCtot&cn=144. (Accessed 22 October 2022).
Global Footprint Network, 2021. Advancing the Science of Sustainability. https://www.footprintnetwork.org/2021/04/26/resource-security-for-poverty-eradication/. (Accessed 22 October 2022).
Gradín, C., Tarp, F., 2019. Investigating growing inequality in Mozambique. S. Afr. J. Econ. 87 (2), 110–138. https://doi.org/10.1111/saje.12215.
Hickel, J., 2020. The sustainable development index: measuring the ecological efficiency of human development in the anthropocene. Ecol. Econ. 167, 106331.
Infante-Amate, J., Krausmann, F., 2019. Trade, ecologically unequal exchange and colonial legacy: the case of France and its former colonies (1962–2015). Ecol. Econ. 156, 98–109.
Jorgenson, A.K., Rice, J., 2012. The sociology of ecologically unequal exchange in comparative perspective. In: Routledge Handbook of World-Systems Analysis. Routledge, pp. 431–439.
Lakner, C., Mahler, D.G., Negre, M., Prydz, E.B., 2019. How Much Does Reducing Inequality Matter for Global Poverty? (English). Policy Research Working Paper; No. WPS 8869; Paper Is Funded by the Strategic Research Program (SRP). World Bank Group, Washington, D.C.
Lavopa, A., Szirmai, A., 2018. Structural modernization and underdevelopment traps. An Empirical Approach, World Development 112, 59–73.
Markandya, A., 2001. Poverty Alleviation and Sustainable Development: Implications for the Management of Natural Capital. Workshop on Poverty and Sustainable Development. International Institute for Sustainable Development, Ottawa.
McGregor, T., Smith, B., Wills, S., 2019. Measuring inequality. Oxf. Rev. Econ. Pol. 35 (3), 368–395.
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. Available at: https://info.undp.org/docs/pdc/Documents/MOZ/EVALUATION%20OF%20PEI%20II%20in%20Mozambique%20FINAL%20REPORT.pdf em. (Accessed 5 August 2018).
MITADER (Ministério da Terra, Ambiente e Desenvolvimento Rural), 2018. Mozambique's Forest Reference Emission Level for Reducing Emissions from Deforestation in Natural Forests. Governo de Moçambique.
Morandi, F., Campbell, D.E., Pulselli, F.M., Bastianoni, S., 2015. Emergy evaluation of hierachically nested systems: application to EU27, Italy and Tuscany and consequences for the meaning of emergy indicators. Ecol. Model. 315, 12–27.
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. Journal of Agriculture and Food Research 4, 100152.
NEAD, 2020. National Environmental Accounting Database v.20. Available at: http://www.emergy-nead.com/home. April 29th 2020.
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.
Odum, H.T., 1996. Environmental Accounting—Emergy and Environmental Decision Making. John Wiley & Sons, New York, p. 370p.
Odusola, A., Cornia, G.A., Bhorat, H., Conceição, P., 2017. (EDS). Income Inequality Trends in Sub-saharan Africa: Divergence, Determinants and Consequences. United Nations Development Programme (UNDP), New York.
Opschoor, J.B., 2007. Environment and poverty. ISS working paper series/general series, 437, 1–38. International Institute of Social Studies of Erasmus University (ISS). Retrieved from. http://hdl.handle.net/1765/18757.
Piñeroet, P., Pérez-Neira, D., Infante-Amate, J., Chas-Amil, M.L., Doldán-García, X.R., 2020. Unequal raw material exchange between and within countries: galicia (NW Spain) as a core-periphery economy. Ecol. Econ. 172, 106621.
Prebish, R., 1950. The Economic Development of Latin America and its Principal Problems (New York).
Radosavljevic, S., Haider, L.J., Lade, S.J., Schlüter, M., 2021. Implications of poverty traps across levels. World Dev. 144, 105437.
Ray, R., 2007. Changes in food consumption and the implications for food security and undernourishment: India in the 1990s. Dev. Change 38 (2), 321–344.
Reed, D., 2002. Poverty and the environment: can sustainable development survive globalization? Nat. Resour. Forum 26 (3), 176–184.
Santos, R., Egger, E.M., Salvucci, V., 2021. Horizontal and Intersecting Inequalities in Mozambique: 1997-2017 (No. 2021/106). WIDER Working Paper. https://www.wider.unu.edu/sites/default/files/Publications/Working-paper/PDF/wp2021-106-horizontal-intersecting-inequalities-Mozambique.pdf.
Sevegnani, F., Giannetti, B.F., Agostinho, F., Almeida, C.M.V.B., 2017. Assessment of municipal potential prosperity, carrying capacity and trade. J. Clean. Prod. 153, 425–434.
Spatafora, N., Irina, T., 2009. Commodity Terms of Trade: The History of Booms and Busts. IMF Working Paper 09205. https://www.imf.org/external/pubs/ft/wp/2009/wp09205.pdf.
Svartzman, R., Althouse, J., 2022. Greening the international monetary system? Not without addressing the political ecology of global imbalances. Rev. Int. Polit. Econ. 29 (3), 844–869.
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.
Tian, X., Geng, Y., Buonocore, E., Sarkis, J., Ulgiati, S., 2018. Uncovering resource losses and gains in China's foreign trade. J. Clean. Prod. 191, 78–86.
Ulandssekretariatet, 2014. Mozambique Labour Market Profile. Danish Trade Union Council for International Development Cooperation, Copenhagen.
UN (United Nations, 2015a. The Millennium Development Goals Report. United Nations, New York.
UN (United Nations, 2015b. Transforming Our World: the 2030 Agenda for Sustainable Development. UN, New York.
UNCTAD, 2019. Selected Sustainable Development Trends in the Least Developed Countries 2019? United Nations Conference on Trade and Development (UCNTAD) (New York and Geneva).
UNCTDA, 2019. Commodities and Development Report 2019. Commodity Dependence, Climate Change, and the Paris Agreement. United Nations, Geneva.
UNCTAD - United Nations Conference on Trade and Development, 2018. Selected Sustainable Development Trends in the Least Developed Countries 2018. Geneva. Available at: https://unctad.org/en/PublicationsLibrary/aldc2018d1_en.pdf.
UNDP (United Nations Development Programme), 2019. Human Development Report 2019: beyond Income, beyond Averages, beyond Today: Inequalities in Human Development in the 21st Century (New York).
UNDP, 2011. Review of HDI Critiques and Potential Improvements. HDR Research Paper.
UNDP-UNEP PEI., 2015. Estudo sobre a Análise de Instrumentos Económicos Ambientais para a Redução da Pobreza em Moçambique. Ministry for Coordination of Environmental Action & UNDP-UNEP. Available at: http://www.biofund.org.mz/wp-content/uploads/2019/01/1548332865-Estudo_sobre_a_An%C3%A1lise_de_Instrumentos_Econ%C3%B3micos_Ambientais_para_a_Redu%C3%A7%C3%A3o_da_Pobreza_em_Mo%C3%A7ambiqu_140115.pdf. (Accessed 6 April 2020).
UNEP - United Nations Environment Programme, 2016. Global Material Flows and Resource Productivity: Assessment Report for the UNEP International Resource Panel, p. 200. Disponível Em: https://www.resourcepanel.org/sites/default/files/documents/document/media/global_material_flows_full_report_english.pdf.
UNEP, 2012. Measuring Progress towards an Inclusive Green Economy. UN Environment, Geneva.
Wackernagel, M., Hanscom, L., Jayasinghe, P., Lin, D., Murthy, A., Neill, E., Raven, P., 2021. The importance of resource security for poverty eradication. Nat. Sustain. 4 (8), 731–738.
WESS (World Economic and Social Survey), 2013. Sustainable Development Challenges. UN DESA, New York.
Wijerathna, D., Bandara, J.S., Smith, C., Naranpanawa, A., 2014. Regional disparities in Sri Lanka: an empirical analysis. Asia-Pacific Development Journal, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) 21 (2), 77–102.
World Bank, 2022. Poverty & equity brief, Africa eastern & southern - Mozambique. Poverty and Equity. https://www.worldbank.org/en/topic/poverty/publication/poverty-and-equity-briefs?qterm_test=mozambique. (Accessed 22 October 2022).
World Bank, 2018. Strong but not broadly shared growth" Mozambique, poverty assessment. Poverty and Equity Global Practice Africa Region. Available at: http://documents.worldbank.org/curated/en/248561541165040969/pdf/Mozambique-Poverty-Assessment-Strong-But-Not-Broadly-Shared-Growth.pdf.