Journal of Sustainable Development of Energy, Water and Environment Systems

http://www.sdewes.org/jsdewes

Year 2025, Volume 13, Issue 3, 1130567

Original Research Article

Catalyzing Circular and Sustainable Economy in African Countries

Faten Loukil*[1]

[1]Department of Economics, University of Tunis, ISG Tunis, 41 Rue de la Liberté, Cité Bouchoucha 2000 Le Bardo, Tunis/ Tunisia,
e-mail: faten.loukil@isg.u-tunis.tn

Cite as: Loukil, F., Catalyzing Circular and Sustainable Economy in African Countries, J.sustain. dev. energy water environ. syst., 13(3), 1130567, 2025, DOI: https://doi.org/10.13044/j.sdewes.d13.0567

ABSTRACT

Demographic and climate projections place resource management as a major concern for the African continent. Nevertheless, the capacity to meet this imminent challenge varies considerably across countries. The paper compares the circular and sustainable pathways of African countries and highlights the factors that facilitate or hinder the transition to a circular economy. To assess the circularity of African economies, the paper introduces two indices: the static Circular Economy Sustainable Development Index and its dynamic counterpart, which measures the average annual growth of the indicators. It employs regression analysis to explore the factors influencing sustainable development trajectories. The findings delineate divergent sustainable trajectories within Africa, highlighting the pivotal role of developmental level in catalyzing the transition towards a Circular Economy. Furthermore, resource rents emerge as a major obstacle to this transformation. Additionally, enhancements in institutional quality and infrastructure exacerbate resource pressures creating substantial barrier to the adoption of a Circular Economy principles.

KEYWORDS

Africa, Circular Economy, Sustainable development, Composite indicators, Barriers.

INTRODUCTION

The concept of the circular economy (CE) has significantly gained attention in recent years, emerging as a viable alternative to the traditional linear model. The CE prioritizes efficient resource allocation while decoupling economic growth from resource consumption [1]. It emphasizes a balance between economic prosperity and environmental sustainability [2]. Additionally, the CE plays a vital role in reducing inequalities, promoting sustainable development [3] and driving job creation [4].

Several developed countries are leading the way in promoting CE. In the EU, national CE policies focused on reducing, reusing, and recycling have significantly contributed to climate neutrality, particularly in Germany and Ireland [5]. In Asia, countries such as Japan and South Korea have placed greater emphasis on public awareness and accountability for resource use [6]. Nevertheless, the full integration of CE into less developed countries has not yet occurred [7], which hinders the global transition to CE [8]. Consequently, there is a strong urgent need to invest in diverse contexts and to gain a comprehensive understanding of the characteristics of the regional CE model [9]. The African continent presents a particularly intriguing case.

* Corresponding author

Approximately 62% of Africa's GDP is closely linked to natural resources, underscoring the importance of transitioning to a CE model [10]. Conversely, the continent faces high poverty rates, unplanned urban development, and vulnerability to climate change [11]. These factors intensify the pressure on the availability of food, water, energy, and land [12].

This prompts the question of whether this fragility is a hindrance to the transition to a CE, or alternatively, a catalyst that encourages countries to embrace change. To what extent does resource availability influence the circular trajectory of African countries? Is weak development a barrier to the integration of circular practices? If so, how can it be overcome? To what extent does the level of development of African countries affect their ability to adopt a circular path?

This research aims to explore the CE model within the African context, an area that has received limited attention in previous research. To this end, the paper first proposes to assess the circular trajectories of African countries using two composite indices. A static index measures a country's efforts over a period, and a dynamic index shows the average annual rate of progress of African countries over time. This evaluation will lead to a typology of African countries based on their efforts to implement the CE. Second, the paper sheds light on the main factors influencing the circular trajectories of African countries.

This will allow better targeting of capacity building in developing countries and enable actors to allocate resources more effectively to remove barriers to the adoption of CE principles.

The complexity of assessing the multidimensionality of circular economy

The literature review reveals a fragmented consensus on the definition of the CE, despite research dating back to the 1960s [13]. While many scholars concur that CE encompasses the reduction, reuse, and recycling of raw materials (the 3Rs), others argue that CE transcends environmental considerations to incorporate socio-economic strategies, thereby contributing to global well-being [14]. The challenge of defining CE's scope, akin to an "umbrella concept" [15], complicates the selection of indicators for measuring circularity[16]. To address the gaps in CE monitoring, some studies [17] suggest developing a composite index, though selecting inclusive criteria remains a challenge, necessitating a methodical approach. Studies indicate that the context and geographical implementation area can influence the sustainability and circularity pathways [18]. Indeed, CE can stray from long-term environmental sustainability when product transformation processes shift one type of pollution to another [19]. A holistic approach ensures interdependence and prevents the focus from being limited to a single Sustainable Development Goal (SDG) [20]. The multidimensional nature of CE raises questions about prioritizing challenges in each context and how different dimensions interact. Addressing CE's main challenge, resource conservation in production and consumption, highlights the critical role of food and energy resources, particularly for African countries [21]. Food and energy are closely linked [22], with rising energy prices affecting the costs of food production, storage, transportation, and distribution. Nexus thinking positions CE as part of an integrated and interdependent sustainability strategy.

Barriers and drivers to CE trajectories for African countries

The literature review underscores the pivotal role of governments in fostering the institutional framework and implementation of a transformative change process conducive to the transition to a CE [23]. Furthermore, it identifies numerous barriers and drivers influencing the transition to CE, with specific implications for the African context [24]. Technical barriers are predominant, as countries require not only access to circular technical solutions but also the capability to implement these solutions swiftly. Information and communication technologies play a crucial role in enhancing these technical capabilities [25]. Technical skills present a significant challenge in Africa, often misaligned with the continent's unique needs and conditions. For example, construction techniques in sub-Saharan Africa mimic those of developed countries, often ignoring the local climate and leading to increased energy consumption due to the lack of an adaptive bioclimatic design approach [26]. The overreliance on unsustainable techniques, such as the use of off-grid solar technology, results in substantial waste and short product lifespans in the region [27]. Additionally, the scarcity of repair skills and the prevalence of a large informal market undermine countries' technical capabilities [28]. Economic barriers also play a role, with market uncertainties and high costs deterring investment. Furthermore, socio-economic inertia serves to exacerbate the reliance on unsustainable solutions and to restrict funding for innovation, especially among small and medium-sized enterprises (SMEs) [29]. A number of studies have highlighted that African countries often overexploit resources without satisfying their needs, a situation that is further compounded by low levels of production investment, inadequate infrastructure, suboptimal resource management, and a lack of human resource capacity [22]. Nevertheless, the vulnerability caused by resource depletion or price volatility can also drive the shift towards CE [23].

In order to identify the factors influencing the transition trajectories towards a circular and sustainable economy in African countries, the remainder of the paper is structured as follows: Section 2 outlines the method for assessing the impact of barriers and drivers on the CE trajectory in African countries, addressing the challenges of data collection. Section 3 presents a typology of African countries based on their CE efforts, models the factors influencing CE in Africa, and offers recommendations to enhance circularity. Section 4 concludes with the main findings of the research.

METHOD

In order to analyse the factors influencing the CE trajectories in African countries, the research method (Figure 1) is divided into two stages. The first stage proposes a measure of circular trajectories in the African context using a multidimensional approach that facilitates comparisons between countries by combining information into a single value. It responds to the openness of the CE concept and takes into account the interaction between resources such as food, water, land and energy and the trade-off with resource efficiency. The use of both static and dynamic composite indices makes it possible to better analyse the trajectories of African countries and measure their capacity to implement CE models. In a static approach, the Circular Economy Sustainable Development Index (CESDI) compares the 54 African countries at a given time[†] and identifies those countries where resource conservation is more critical. Thus, a high CESDI index value, close to 1, indicates the country's ability, compared to other African Countries, to preserve its food and energy resources and distribute them more effectively.

From a dynamic perspective, the circularity of the economy is measured by the average annual growth (aag) of the indicators. The CESDIaag captures the improvements made by countries to ensure resource conservation. The higher the CESDIaag index value, the stronger the dynamic of CE and natural resource preservation. This approach overcomes the problem of non-availability of information for certain indicators in the same year, making it possible to compare average annual progress over a given period. In terms of decision-making, the two indices jointly define the priority areas that deserve support to move towards sustainable and circular development.

The second stage highlights the socio-economic, technical and institutional barriers and drivers that influence circularity trajectories in Africa. A multiple regression model is used to identify the factors that explain the CESDI and CESDIaag indices.

[†] Given that the data used come from different data sources and contain different time periods, CESDI is built using different analysis periods in order to cope with the limited availability of data.

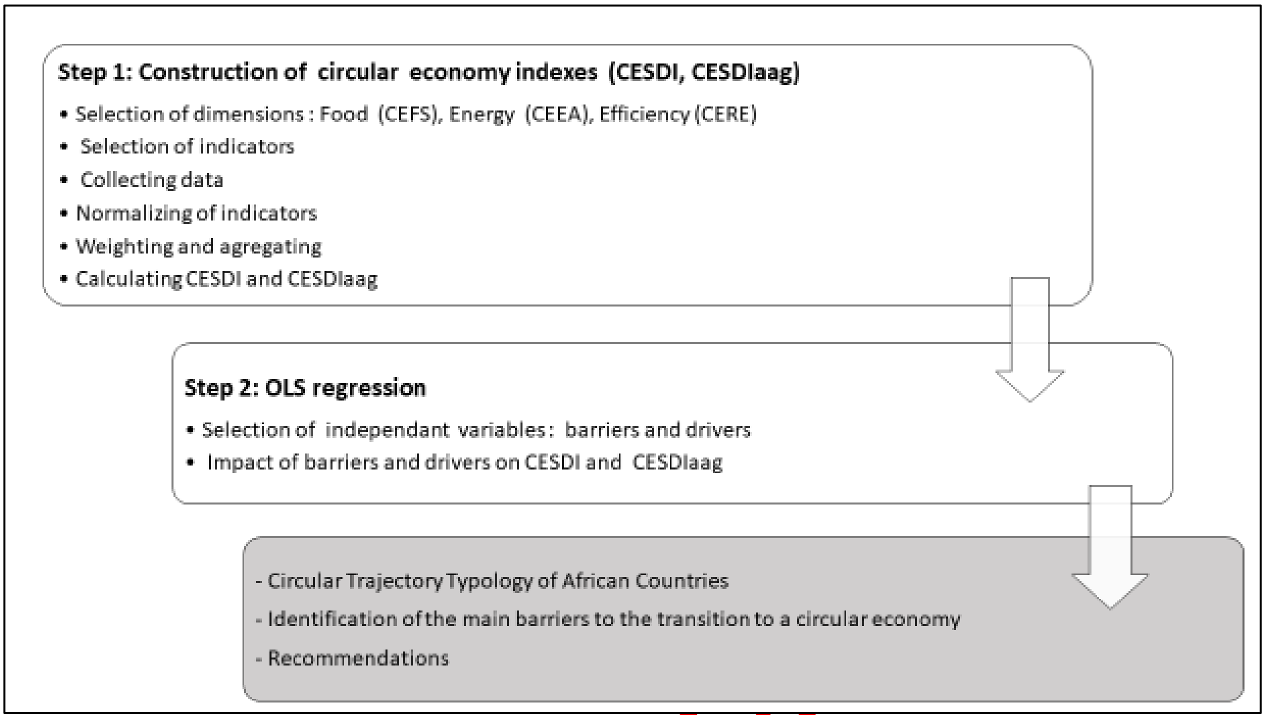

Figure 1. Research purpose steps

Construction of circular economy indexes

Methods for constructing a composite index [30], propose a multi-step approach: defining the object of study with reference to a theoretical context, selecting suitable simple indicators, standardizing each indicator and choosing the aggregation method. While there is consensus on the above steps, it is important to recognize that the substitutability or non-substitutability of the indicators chosen, the aggregation method (complex or simple), the relative or absolute comparison between countries and the indicator weighting method all have a significant impact on the construction of the CESDI and CESDIaag indices.

Selection of indicators and collecting data. According to the OECD recommendations [31], the method of indicator selection refers to the theoretical framework and takes into account their relevance, accessibility and availability. The selection must ensure a trade-off between the inclusion of redundant variables and the risk of losing information. For this research, the selection of variables (Table 1) is related to a literature review [3], which highlights the CE principles that include the reduction, reuse and recycling of materials and enable the conservation and efficient use of food and energy resources.

The indices cover three dimensions and a total of twelve variables using a holistic approach that recognizes the interconnectedness of resources. First, the food-forest-water nexus is at the heart of sustainable food security. Second, the energy dilemma lies in determining the optimal trade-off between promoting renewable energy and ensuring equitable access to electricity and depends in environmental regulation measured by three indicators: the Nationally Determined Contributions (NDC)[‡] indicator measures mitigation and adaptation targets, the number of Multilateral Environmental Agreements (MEA) in force measures countries' commitment to environmental issues and the number of National Environmental Policies (NEP) in force measures the level of current national efforts to regulate the environment. Finally, for resource efficiency, the Domestic Material Consumption (DMC) per GDP indicator, defined as the global amount of material (biomass, fossil fuels, metal ores and non-metallic minerals) used by the economy, measures the national intensity of resource use [32]. It includes domestic

[‡] All African countries have ratified the Paris Agreement except Libya

extraction related to the raw material, as well as the physical import of the material, and excludes the physical export.

Table 1. Variables measuring circular economic sustainable development indexes (CESDI and CESDIaag)

Dimensions of CESDI/ CESDIaag	Variables	CE principles
Circular economy for food security (CEFS)	Agricultural land per capita	Reuse and regenerate land under demographic pression
	Forest area per Land area	Reduce deforestation externality
	Total renewable water resources	Reuse renewable water resources
	Total population with access to drinking water	Equitable access to drinking water
Circular economy for energy availability (CEEA)	CO_2 per capita	Reduce carbon emission
	Percentage of renewable energy consumption	Reduce fossil energy and reuse of renewable energy
	Environmental regulation (Composite indicator)	Reduce pollution and resource depletion.
	Access to electricity	Equitable access to energy
Circular economy for efficient resource (CEER)	Domestic material consumption per GDP	Reduce material consumption
	Waste generation	Reduce waste generation
	Recycling rate	Recycling
	GDP per capita	Ability to create value and richness

It is possible to enrich the index with other indicators. However, data availability and index simplicity have been taken into account. The construction of the index is challenged by the unavailability of data for specific dates. In many cases, several sources are utilized to complete the missing data, as shown in Table 2. To ensure data reliability, all referenced sites rely on internationally recognized official sources or the public entities that produce them. For the waste generation indicator, the World Bank's 2016 estimate [33] and the latest available data from World Bank reports are used to calculate CESDIaag.

Table 2. Method for collecting data for CESDI and CESDIaag

Indicator	Sources	CESDI Year	CESDIaag Annual growth rate between
$I^{1.0}$: Agricultural land per capita	[34]For Sudan [35], South Sudan [36], Eritrea[37].	2016	2010-2016
$I^{2.0}$: Forest area/ Land area	[34]For Sudan [36], South Sudan [38]	2016	2010-2016. For South Sudan 2013-2016

$I^{3.0}$:Total renewable water resources	[39]	2017	2012-2017
$I^{4.0}$:Total population with access to drinking water	[39]	2015	2012-2015
$I^{5.0}$: Air pollution	[34]	2016	2010-2016 For Seychelle, 2012-2016
$I^{6.0}$: Environmental regulation	Composite indicator calculated by the author		
$I^{6.1}$:NDC	[40]	2015	2010 -2015
$I^{6.2}$: NEP	[41]	2020	2010-2020
$I^{6.3}$: MEA	[41]	2020	2010-2020
$I^{7.0}$:Renewable energy consumption	[34]	2015	2010-2015. For South Sudan 2012-2015
$I^{8.0}$: Access to electricity	[34]	2018	2010-2018. For Equatorial guinea, 2011-2018
$I^{9.0}$: DMC per GDP	[42]	2015	2010-2015. For South Soudan, 2012-2015
$I^{10.0}$: Waste generation	[43] [33]	2016 (estimated data)	Last available data -2016 (estimated data)
$I^{11.0}$: GDP per capita	[34]	2016	2010-2016
$I^{12.0}$: Recycling rate	[43] [33]	Last available data	Last available data: after 2015-before 2015

For certain countries, such as Equatorial Guinea, Eswatini and Somalia, data availability is limited. To address this, the average waste generation corresponding to each country's development level in 2010 was applied: upper middle income for Equatorial Guinea and lower middle income for Eswatini and Somalia.

Information on recycling is also scarce for African countries. This situation is further complicated by the strong presence of the informal recycling sector in Africa. The lack of available data suggests the absence of a formal national system and recycling strategy. It also reflects a reluctance to integrate the informal sector and signals a potential worsening of the situation without appropriate measures. Due to the scarcity of information, the absence of official data in this study is interpreted as a lack of formal and inclusive recycling activities, recorded as zero.

The construction of the indices allows indicators to be interchangeable in their contribution to circularity. Strong performance in one area such as reducing waste generation can compensate for weaker performance in another such as reduce materiel consumption or reduce deforestation, reflecting the specific priorities and circumstances of each country.

Method of Normalizing indicators

Normalization is required before aggregation and allows comparison of indicators on different scales by transforming them into normalized values in the range 0-1. The normalization method depends on the type of comparison (absolute or relative). A relative comparison was chosen to effectively assess and benchmark the performance of different African countries. The value of the normalized data that tends to 1, indicates a significant contribution to the country's circularity compared to other African countries. On the other hand, when the value reaches 0, the country's performance is weak compared to all African countries.

Table 3 summarises the normalization approach by presenting selected indicators with different units, each reflecting a key dimension of the CE in Africa. The data are collected for the same year to facilitate comparison. The contribution column specifies whether an indicator positively or negatively affects CE performance. The Max and Min columns indicate the countries with the highest and lowest values for each indicator, respectively. These insights reveal regional disparities and diverse circular economy trajectories across Africa, facilitating cross-country comparisons and highlighting sustainability performance gaps.

The max-min method is applied for normalization, utilizing equations 1 and 2. For both equations, the $y_j^{i.s}$ represents the normalized value of the indicator $I^{i.s}$ for the given country j, while $X_j^{i.s}$ denotes the raw value of the same indicator for country j.

The parameters are defined as follows: j varies from 1 to N where N = 54 represents the number of African countries, i ranges from 1 to 12 representing different indicators included in the construction of CESDI and CESDIaag indices, s takes the value 0 when the indicator is directly integrated into the calculation of the CESDI and CESDIaag indices and ranges from 1 to 3 for indicators used to construct the environmental regulation composite indicator: $y^{6.0}$, $maxX^{i.s}$ *and* $minX^{i.s}$ are the maximum and minimum Value of $X_j^{i.s}$ across all countries j.

$$y_j^{i.s}(X_j) = \frac{X_j^{i.s} - minX^{i.s}}{maxX^{i.s} - minX^{i.s}} \quad (1)$$

$$y_j^{i.s}(X_j) = \frac{X_j^{i.s} - maxX^{i.s}}{minX^{i.s} - maxX^{i.s}} \quad (2)$$

Equation 1 normalises data where the high value indicates more circularity and contribution to Africa's sustainable development challenges, such as agricultural land, total renewable water resources and other indicators mentioned in Table 3. The following example illustrates the calculation method for the normalised indicator of Agricultural land per capita in Gabon.

In this case, i=1, s = 0 and j = Gabon. The raw value of indicator is $X_{Gabon}^{1.0}$ = 0,0317.

From Table 3, the maximum value is $maxX^{1.0}$= 0,16 (observed in Namibia) and the minimum value is $minX^{1.0}$ = 0,00016 (observed in Seychelles).

The normalised indicator value is then calculated as follows:

$$y_{Gabon}^{1.0}(X_{Gabon}) = \frac{X_{Gabon}^{1.0} - minX^{1.0}}{maxX^{1.0} - minX^{1.0}} = 0{,}197$$

Equation 2, on the other hand, normalises data where a low value indicates more contribution to CE, such as waste generation, air pollution and domestic material consumption.

For Gabon, equation 2 can be used to calculate the normalized indicator $y^{5.0}$ for Air pollution. In this case, i= 5, s= 0. The air pollution value for Gabon is $X_{Gabon}^{5.0}$ = 0,2474, recorded in the database [34]. The minimum value, $minX^{5.0}$= 0,0256, is observed in Central African Republic while the maximum value, $maxX^{5.0}$= 8,480, is recorded in Uganda.

The normalized indicator value is then calculated as:

$$y^{5.0}_{Gabon}\,(X_{Gabon}) = \frac{X^{5.0}_{Gabon} - maxX^{5.0}}{minX^{5.0} - maxX^{5.0}} = 0{,}973$$

For CESDIaag, $X_j^{i.s}$ is replaced by $X_{j\;aag(Tf-Tk)}^{i.s}$ in equations 1 and 2 to normalise the average annual growth for the rate of indicator $I^{i.s}$ over a given period (T_f-T_k).

$X_{j\;aag(Tf-Tk)}^{i.s}$ represents the average annual growth rate of the indicator $X_j^{i.s}$ over the period (T_f-T_k) as shown in equation 3, $maxX^{i.s}_{aag}$ *and* $minX^{i.s}_{aag}$ are the maximum and minimum value of $X_{j\;aag(T_f-T_k)}^{i.s}$ across all countries. For each indicator, T_f is the most recent date and T_k is the initial date. So,

$$X_{j\;aag(T_f-T_k)}^{i.s} = \sqrt[(Tf-Tk)]{\frac{X^{i.s}_{j\;T_f}}{X^{i.s}_{j\;T_k}}} - 1 \qquad (3)$$

Thus, in the case of Gabon, and referring to the indicator agricultural land per capita, T_f corresponds to the year 2016 and T_k to the year 2010, as specified in Table 2, so (T_f-T_k) = 6. On this basis, it can be deduced that:

$$X^{1.0}_{Gabon\;aag(6)} = \sqrt[(6)]{\frac{X^{1.0}_{Gabon\;2016}}{X^{1.0}_{Gabon2010}}} - 1 = -0{,}034729$$

The normalized value is then deduced by applying Equation 1, given that $maxX^{1.0}_{aag} = -0{,}00428$ *and* $minX^{1.0}_{aag} = -0{,}0839$, so $y^{1.0}_{aag(6)Gabon}\,(X_{Gabon}) = 0{,}617$

Table 3. Method of Normalizing indicators for CESDI

Indicator	Unit	Year	$maxX^{i.s}$	$minX^{i.s}$	Contribution
$y^{1.0}$: Agricultural land/ Total population	sq.km/ cap	2016	0,16 Namibia	0,00016 Seychelles	+
$y^{2.0}$: Forest area/ Land area	%	2016	90,04 Gabon	0,074 Egypt	+
$y^{3.0}$:Total renewable water resources	m3/cap/ year	2017	158145 Congo	13,75 Seychelles	+
$y^{4.0}$: Total population with access to drinking water	(%)	2015	100	47,9 Equatorial Guinea	+
$y^{5.0}$: Air pollution	CO2/cap	2016	8,480 Uganda	0,0256 Central. A.R	-
$y^{6.0}$: Environmental regulation					+
$y^{6.1}$: NDC[a]	%	2015	89 Namibia	0[b] South Africa	+
$y^{6.2}$: NEP		2020	76 South Africa	0	+
$y^{6.3}$: MEA		2020	449	43	+

			Morocco	South Sudan	
$y^{7.0}$: Renewable energy consumption	%	2015	100	0 Algeria	+
$y^{8.0}$: Access to electricity	% population	2018	100	11,02 Burundi	+
$y^{9.0}$: GDP per capita	constant 2010 USD	2016	13606,09 Seychelles	90,72 Somalia	+
$y^{10.0}$: DMC per GDP	Kg/ USD 2005	2015	15,76 Sierra Leone	0,16 Seychelles	-
$y^{11.0}$: Waste generation	Kg/cap/day	2016	1,57 Seychelles	0,11 Lesotho	-
$y^{12.0}$: Recycling rate	%	Last available data	28 South Africa	0	+

a For Tanzania, the NDC ranges from 10 to 20, with the average value of 15 considered.
b South Africa does not commit to a reduced level, but it offers a three-phase approach: peak, plateau and decline, and an emission level between 398-614 MT CO2 eq.

Weights and aggregation

The normalized data are aggregated. Thus, the CESDI is a composite for three dimensions having the same ponderation as mentioned in equation 4.

$$CESDI_J = \frac{1}{3}[CEFSj + CEEAj + CEERj] \qquad (4)$$

Each dimension is composed of four equally weighted indicators, as explained in equation 5.

$$\text{with } CEFSj = \frac{1}{4}\sum_{i=1}^{4} y_j^{i.0},\ CEEAj = \frac{1}{4}\sum_{i=5}^{8} y_j^{i.0}\ ,\ CEERj = \frac{1}{4}\sum_{i=9}^{12} y_j^{i.0} \qquad (5)$$

Thus, the composite CESDI index is the sum of 12 indicators, as specified in equation 6. All integrated indicators are simple, except for the one related to environmental regulation, which is itself a composite indicator consisting of three indicators, as mentioned in equation 7. So,

$$CESDI_J = \propto_i \sum_{i=1}^{12} y_j^{i.0} \qquad (6)$$

$$y_j^{6.0} = \frac{1}{3}\left[y_j^{6.1} + y_j^{6.2} + y_j^{6.3}\right] \qquad (7)$$

with $\propto_i$ is the weight given to the indicator i. The value $\propto_i$ indicates the degree of importance of each variable in the construction of the index. The choice of the weight given to each dimension is an arbitrary decision [30]. In this research, the same weight is assigned to the indicators to emphasize the equal importance of each dimension and each indicator, while the variables are combined using an additive function.

The classification of countries based on the method of nested averages will make it possible to establish a typology of African countries in terms of their static and dynamic circular economy performances.

Ordinary Least Square regression

In order to measure the impact of barriers and drivers on the CE trajectory of African countries, the following models represented by equations 8 and 9 are considered:

$$\text{Model 1}: \quad CESDIj = \beta_1 Z_{1j} + \beta_2 Z_{2j} + \cdots . \beta_k Z_{kj} + \varepsilon_{kj} \qquad (8)$$

$$\text{Model 2}: \quad CESDIaagj = \beta_1 Z_{1j} + \beta_2 Z_{2j} + \cdots . \beta_k Z_{kj} + \varepsilon_{kj} \qquad (9)$$

Where CESDI and CESDIaag are the dependent variables, β_k are the coefficients of the regression and Z_{kj} are the different independent variables for the countries j, ε is the error term.

In this study, Stata software was used to perform Ordinary Least Squares (OLS) regression analysis to estimate the association between the independent variables (CESDI, CESDIaag) and different barriers and drivers affecting the CE. OLS regression, a linear modeling technique, was chosen for its ability to model relationships involving multiple dependent and independent variables [44]. The factors influencing CE (Table 4) are indicative of the barriers and drivers discussed in the literature presented in the first section. Some factors were omitted from the models due to multicollinearity concerns.

The OLS method is a statistical technique that seeks to minimise the sum of the squared of differences (residuals) between observed values and those predicted by the model. The estimated β coefficients quantify the individual contribution of each independent variable, indicating the marginal effect of each explanatory variable on the dependent variable. Under the standard assumptions of linearity, homoscedasticity, and error independence, OLS produces unbiased and efficient estimators with the lowest possible variance. To assess the statistical significance of an explanatory variable, hypothesis testing is performed on its corresponding β coefficient. The null hypothesis (H_0: $\beta_k = 0$) states that the variable has no effect on the dependent variable. If this hypothesis is rejected, it suggests that the variable significantly contributes to predicting or explaining the target variable.

Table 4. Factors impacting circular economy trajectories in African countries

Factors	Variables	Description	Source	Year
Technical	Technical cooperation grants (BoP, current US$) Technic	Captures the amount of subsidies intended to strengthen the transfer of technical skills.	[34]	2017
	Population living in slums (% of urban population) Slums	Measures the infrastructure barriers.	[34], [45], [46]	2018 2014 Mauritius Libya, Erythrea, Somalia, South Sudan, Seychelles and Djibouti
Socio-economic	Total natural resources rents (% of GDP) Rent	Measures a country's production structure and the share of rent in the value created.	[34]	2018 2015 South Sudan 2011 Eritrea
	Human development index HDI	Measures the country's level of socio-economic development.	[47]	2018 2012 Somalia

	Foreign direct investment, net inflows (% of GDP) FDI	Captures the transfer of technology and know-how between countries.	[34]	2019 2015 South Sudan 2011 Eriteria
Institutionnal	Government effectiveness Government	Estimates the perceptions of the quality of public services.	[34]	2019

RESULTS AND DISCUSSION

The results provide valuable insights into the potential for a CE within the African context characterized by economic, climatic, and institutional vulnerabilities. Firstly, the findings highlight the efforts of African countries in key areas such as food, energy, and resource efficiency. This allows for the identification of circular trajectories for 54 African countries, relying on the CESDI and CESDIaag indices. The second part presents an analysis of the technical, socio-economic, and institutional factors that influence the circular trajectories of African countries.

Circular economy trajectories of African countries

Figure 2 provides an analysis of the static and dynamic circular performances of African countries in terms of food (CEFS, CEFSaag), energy (CEEA, CEEAaag) and resource efficiency (CEER, CEERaag).

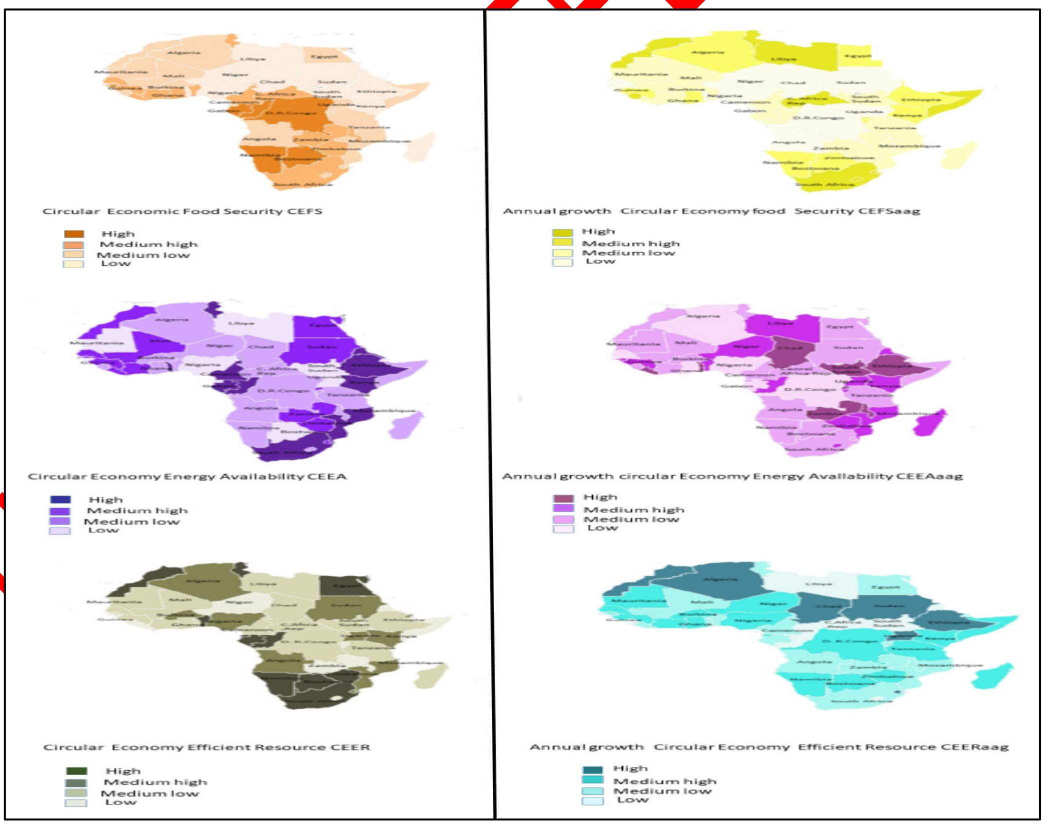

Figure 2. Performance levels of African countries related to CEFS, CEFSaag, CEEA, CEEAaag, CEER and CEERaag

For food, the CEFS map shows that neighbouring countries face similar water, land and deforestation nexus for both low and high CEFS countries. This finding is confirmed by the CEFSaag map, which delineates the dynamic perspective and reveals a clustering of low dynamic countries in the central and western region facing significant challenges, in particular political conflicts that impede the rapid implementation of essential economic and political reforms in the agricultural sector [48]. For energy, the CEEA map shows that the main producers of fossil energy (oil and gas) in Africa, such as Nigeria, Algeria, Libya and Egypt [49], are not well classified according to CEEA. The abundance of fossil natural resources prevents the consideration of long-term strategies, such as the transition to renewable energy and the reduction of pollution. Renewable energy is not considered as part of a sustainable and equitable energy access strategy for African countries, as also mentioned by other studies [50].The CEEAaag map shows that Malawi, Liberia, Rwanda, Ethiopia and Seychelles have made the most efforts to strengthen energy availability, while Algeria, Chad, Djibouti and Senegal are the least developed countries on this axis. In terms of resource efficiency, the CEER map highlights the ability of African countries to decouple growth from resource use. It indicates that the South Africa, the Republic of the Congo, Equatorial Guinea and Mauritius are the best performers in the static approach (CEER). Using the dynamic approach, Uganda, Comoros, Ethiopia, Sudan, Mauritius and Eswatini (Swaziland) have made the most progress.

Appendices 1 and 2 show the results of applying the CESDI and CESDIaag indices to 54 African countries and compare their performance in static and dynamic approaches. This ranking serves as the basis for defining a typology of African countries in terms of their circular and sustainable performances as illustrated in Figure 3.

Each country is placed on the graph according to its performance on the CESDI (x-axis) and the CESDIaag (y-axis). Thus, the first group "constantly moving forward" is made up of countries whose CESDI and CESDIaag performances are above average. These countries are in an interesting CE dynamic. This group includes five island countries: Cape Verde, Sao Tome and Principe, Comoros, Mauritius and the Seychelles. Despite their vulnerability to climate change, they have risen to the challenge of implementing optimal resource management. Group 2 " be awake" is made up of countries that have a low CESDI but a high CESDIaag. Some disadvantaged and low level of development countries particularly in the eastern region, are making good progress that will allow them to catch up and move to CE in the future. These include countries such as Ethiopia, Somalia, Rwanda, Lesotho and Burundi. On the other hand, group 3 " stay stagnant " is made up of countries with high CESDI and low CESDIaag values. The countries in this group have interesting circular performances compared to other African countries, but are not in a circular dynamic that allows predicting future progress. Many of these countries are located in West Africa. Some of them have benefited from an abundance of natural resources, especially fossil resources. The last group "unable" represents the countries that are in the most critical situation with a low CESDI and a low CESDIaag. It includes countries such as South Sudan, Niger, Libya and Togo.

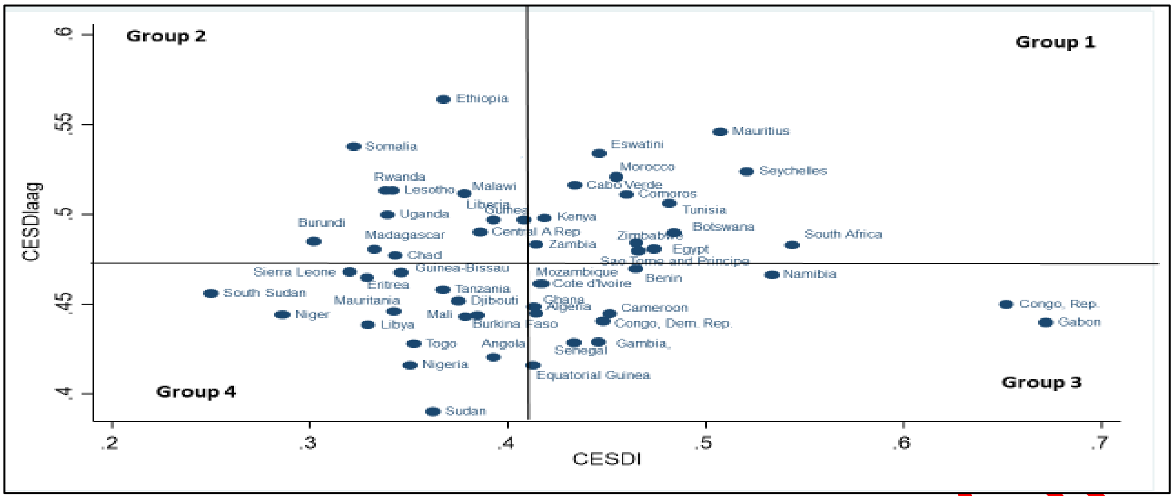

Figure 3. Typology of African countries according to CESDI and CESDIaag performances

Barriers and drivers to circular economy for African countries

The results of the regressions in Table 5 provide further explanation of the typology of African countries. The R-squared indicates that more than 97% of CESDI and CESDIaag are explained by the independent variables, which confirms the goodness of fit of the models. Additionally, the significance levels reflect the statistical confidence in the observed relationships: *** denotes a highly significant result with a probability of randomness below 1%, ** indicates statistical significance with a probability below 5%, and * represents moderate significance with a probability of randomness up to 10%.

The model 1 results demonstrate a positive and significative relation between CESDI and HDI. This relationship is significant at 99% level and indicates that human development has an impact on the ability of African countries to adopt circular and sustainable approaches. The higher a country's level of development, the more likely it is to adopt the principles of a CE. Conversely, low development represents a significant barrier to the transition to a CE. This result is in line with Beckerman's work [51] on the Kuznets Environmental Curve which demonstrates that development is the key to better environmental quality. The positive and significative relation between CESDIaag and HDI in the model 2 confirms the importance of human development as the driving force behind a circular trajectory.

The estimation results show a significant and negative relationship between resource rents and CESDIaag indicating the more the economy of an African country is based on resource rents, the weaker the dynamic of transition towards a circular economy.

Table 5. The results of OLS regression

	Model 1: CESDI		Model 2 : CESDIaag	
	B	t	β	t
Technic	-1.37e-10	-1.12	6.04e-11	0.52
Rent	0.001	1.03	-0.002	-1.94*
HDI	0.666	17.51***	0.643	17.81***
FDI	0.001	0.69	0.002	1.12
Slums	0.001	1.65	0.002	4.01***
Government	0.008	0.33	-0.335	-1.73*
R squared	0.9769		0.982	

Prob > F	0.0000	0.0000

Notes : *** = p < 0.01, ** = p < 0.05, * = p < 0.10.

The government effectiveness variable is significant and negative in the model 2. Circular dynamics are highest in countries where the perception of the quality of public services is lowest.

This result may appear counterintuitive, but it underscores the intricate nexus between the quality of institutions and the pressure on resources in the African context. Indeed, some studies have demonstrated that low institutional quality is indicative of a high level of corruption, which reduces the attractiveness of resource-intensive projects, thereby contributing to enhanced environmental preservation [52]. Consequently, the quality of institutions does not appear to be a driver behind the transition to the CE in Africa. This finding is corroborated in countries that also exhibit unsustainable infrastructure, as measured by the proportion of urban population living in slums. The positive and significant relationship between CESDIaag and the percentage of the population living in slums shows that it is in countries with the highest rate of slums that progress in resources conservation is most significant. Thus, the quality of the infrastructure is conducive to resource-intensive projects. The results of estimated models shows that the transfer of technical skills (Technic) and direct foreign investment (FDI) do not have a significant impact on the transition to the CE in the African context. In the contemporary African context, the transfer of techniques does not contribute to resource circularity.

CONCLUSION

The paper shows divergent trajectories towards circular and sustainable development. Using the OLS method to identify factors that either hinder or drive circular transitions in African countries, it draws the following conclusions. It argues that Countries with a high level of human development have the capacity to make the transition to CE. However, this transition is slowed by economic barriers, especially when economic activity is based on resource rents. This leads to inertia towards change, low acceptance of new clean technologies and resources curse.

Moreover, the reinforcement of institutional and infrastructural quality does not facilitate the transition to a CE; rather, it exerts additional pressure on African countries' resources.

Given this situation, public policies must promote the diversification of African economies in order to move away from the resource rent economy. It is also important to give priority to local African techniques rather than transferring techniques that are not adapted to the African context. There is an urgent need to integrate international cooperation and capacity-building efforts into sustainable development objectives, and to ensure that improving the quality of institutions and infrastructure does not lead to additional pressure on African countries' resources.

NOMENCLATURE

Abbreviations

CE	Circular Economy
CEEA	Circular Economy for Energy Availability
CEER	Circular Economy for Efficient Resource
CEFS	Circular Economy for Food Security
CESDI	Circular Economy Sustainable Development Index
DMC	Domestic Material Consumption
GDP	Gross Domestic Product

MEA	Multilateral Environmental Agreements
NDC	Nationally Determined Contributions
NEP	National Environmental Policies
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
SDG	Sustainable Development Goal
SMEs	Small and Medium-sized Enterprises

REFERENCES

1. W. R. Stahel, ‘The circular economy’, *Nature*, vol. 531, no. 7595, pp. 435–438, 2016.
2. J. Kirchherr, D. Reike, and M. Hekkert, ‘Conceptualizing the circular economy: An analysis of 114 definitions’, *Resour. Conserv. Recycl.*, vol. 127, pp. 221–232, Dec. 2017, https://doi.org/10.1016/j.resconrec.2017.09.005.
3. J. Kirchherr, N.-H. N. Yang, F. Schulze-Spüntrup, M. J. Heerink, and K. Hartley, ‘Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions’, *Resour. Conserv. Recycl.*, vol. 194, p. 107001, Jul. 2023, https://doi.org/10.1016/j.resconrec.2023.107001.
4. S. Caldera, R. Jayasinghe, C. Desha, L. Dawes, and S. Ferguson, ‘Evaluating Barriers, Enablers and Opportunities for Closing the Loop through “Waste Upcycling”: A Systematic Literature Review’, *J. Sustain. Dev. Energy Water Environ. Syst.*, vol. [10], no. [1], p. [1]-[20], Mar. 2022.
5. V. Sanz-Torró, C. Calafat-Marzal, J. M. Guaita-Martinez, and V. Vega, ‘Assessment of European countries’ national circular economy policies’, *J. Environ. Manage.*, vol. 373, p. 123835, Jan. 2025, https://doi.org/10.1016/j.jenvman.2024.123835.
6. S. L. Ngan *et al.*, ‘Prioritization of sustainability indicators for promoting the circular economy: The case of developing countries’, *Renew. Sustain. Energy Rev.*, vol. 111, pp. 314–331, Sep. 2019, https://doi.org/10.1016/j.rser.2019.05.001.
7. P. Guarnieri *et al.*, ‘Transitioning towards a circular economy under a multicriteria and the new institutional theory perspective: A comparison between Italy and Brazil’, *J. Clean. Prod.*, vol. 409, p. 137094, Jul. 2023, https://doi.org/10.1016/j.jclepro.2023.137094.
8. B. Suárez-Eiroa, E. Fernández, and G. Méndez, ‘Integration of the circular economy paradigm under the just and safe operating space narrative: Twelve operational principles based on circularity, sustainability and resilience’, *J. Clean. Prod.*, vol. 322, p. 129071, Nov. 2021, https://doi.org/10.1016/j.jclepro.2021.129071.
9. P. Dewick, A. M. de Mello, J. Sarkis, and F. K. Donkor, ‘The puzzle of the informal economy and the circular economy’, *Resour. Conserv. Recycl.*, vol. 187, p. 106602, Dec. 2022, https://doi.org/10.1016/j.resconrec.2022.106602.
10. A. E. Outlook, ‘Mobilizing private sector financing for climate and green growth in Africa’, *Abidj. Afr. Dev. BankOrganization Econ. Coop. Dev. Nations Dev. Programme*, 2023.
11. G. O. Oduyemi, T. Owoeye, and O. B. Adekoya, ‘Health outcomes and the resource curse paradox: The experience of African oil-rich countries’, *Resour. Policy*, vol. 73, p. 102201, Oct. 2021, https://doi.org/10.1016/j.resourpol.2021.102201.

12. L. Nyiwul, 'Climate change adaptation and inequality in Africa: Case of water, energy and food insecurity', *J. Clean. Prod.*, vol. 278, p. 123393, Jan. 2021, https://doi.org/10.1016/j.jclepro.2020.123393.
13. D. Reike, W. J. V. Vermeulen, and S. Witjes, 'The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options', *Resour. Conserv. Recycl.*, vol. 135, pp. 246–264, Aug. 2018, https://doi.org/10.1016/j.resconrec.2017.08.027.
14. K. Hartley, R. van Santen, and J. Kirchherr, 'Policies for transitioning towards a circular economy: Expectations from the European Union (EU)', *Resour. Conserv. Recycl.*, vol. 155, p. 104634, Apr. 2020, https://doi.org/10.1016/j.resconrec.2019.104634.
15. A. S. Homrich, G. Galvão, L. G. Abadia, and M. M. Carvalho, 'The circular economy umbrella: Trends and gaps on integrating pathways', *J. Clean. Prod.*, vol. 175, pp. 525–543, Feb. 2018, https://doi.org/10.1016/j.jclepro.2017.11.064.
16. V. Elia, M. G. Gnoni, and F. Tornese, 'Measuring circular economy strategies through index methods: A critical analysis', *J. Clean. Prod.*, vol. 142, pp. 2741–2751, Jan. 2017, https://doi.org/10.1016/j.jclepro.2016.10.196.
17. F. Silvestri, F. Spigarelli, and M. Tassinari, 'Regional development of Circular Economy in the European Union: A multidimensional analysis', *J. Clean. Prod.*, vol. 255, p. 120218, May 2020, https://doi.org/10.1016/j.jclepro.2020.120218.
18. A. P. M. Velenturf and P. Purnell, 'Principles for a sustainable circular economy', *Sustain. Prod. Consum.*, vol. 27, pp. 1437–1457, Jul. 2021, https://doi.org/10.1016/j.spc.2021.02.018.
19. N. Millar, E. McLaughlin, and T. Börger, 'The Circular Economy: Swings and Roundabouts?', *Ecol. Econ.*, vol. 158, pp. 11–19, Apr. 2019, https://doi.org/10.1016/j.ecolecon.2018.12.012.
20. R. Panchal, A. Singh, and H. Diwan, 'Does circular economy performance lead to sustainable development? – A systematic literature review', *J. Environ. Manage.*, vol. 293, p. 112811, Sep. 2021, https://doi.org/10.1016/j.jenvman.2021.112811.
21. 'Cities and a circular economy for food – overview'. https://www.ellenmacarthurfoundation.org/cities-and-a-circular-economy-for-food/overview (accessed Feb. 02, 2025).
22. F. Muhirwa *et al.*, 'Alert in the dynamics of water-energy-food production in African countries from a nexus perspective', *Resour. Conserv. Recycl.*, vol. 194, p. 106990, Jul. 2023, https://doi.org/10.1016/j.resconrec.2023.106990.
23. A. de Jesus and S. Mendonça, 'Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy', *Ecol. Econ.*, vol. 145, pp. 75–89, Mar. 2018, https://doi.org/10.1016/j.ecolecon.2017.08.001.
24. C. Pasqualotto, D. Callegaro-De-Menezes, and C. S. L. Schutte, 'An Overview and Categorization of the Drivers and Barriers to the Adoption of the Circular Economy: A Systematic Literature Review', *Sustainability*, vol. 15, no. 13, Art. no. 13, Jan. 2023, https://doi.org/10.3390/su151310532.
25. J. Barrie, M. Anantharaman, M. Oyinlola, and P. Schröder, 'The circularity divide: What is it? And how do we avoid it?', *Resour. Conserv. Recycl.*, vol. 180, p. 106208, May 2022, https://doi.org/10.1016/j.resconrec.2022.106208.
26. P. V. Genovese and A. N. Zoure, 'Architecture trends and challenges in sub-Saharan Africa's construction industry: A theoretical guideline of a bioclimatic architecture evolution based on the multi-scale approach and circular economy', *Renew. Sustain. Energy Rev.*, vol. 184, p. 113593, Sep. 2023, https://doi.org/10.1016/j.rser.2023.113593.
27. C. Kinally, F. Antonanzas-Torres, F. Podd, and A. Gallego-Schmid, 'Off-grid solar waste in sub-Saharan Africa: Market dynamics, barriers to sustainability, and circular economy

solutions', *Energy Sustain. Dev.*, vol. 70, pp. 415–429, Oct. 2022, https://doi.org/10.1016/j.esd.2022.08.014.

28. F. Khan and Y. Ali, 'A facilitating framework for a developing country to adopt smart waste management in the context of circular economy', *Environ. Sci. Pollut. Res.*, vol. 29, no. 18, pp. 26336–26351, Apr. 2022, https://doi.org/10.1007/s11356-021-17573-5.
29. M. O. Erdiaw-Kwasie, M. Abunyewah, and C. Baah, 'A systematic review of the factors – Barriers, drivers, and technologies – Affecting e-waste urban mining: On the circular economy future of developing countries', *J. Clean. Prod.*, vol. 436, p. 140645, Jan. 2024, https://doi.org/10.1016/j.jclepro.2024.140645.
30. M. Mazziotta and A. Pareto, ' A. Methods for constructing composite indices: One for all or all for one. Rivista Italiana di Economia Demografia e Statistica, Vol 67, N°2, pp 67-80. 2013.
31. OECD, European Union, and Joint Research Centre - European Commission, *Handbook on Constructing Composite Indicators: Methodology and User Guide*. OECD, 2008.
32. 'SDG Indicators — SDG Indicators''. Accessed: Feb. 02, 2025. [Online]. Available: https://unstats.un.org/sdgs/metadata/files/Metadata-08-04-02.pdf.
33. S. Kaza, L. C. Yao, P. Bhada-Tata, and F. V. Woerden, 'What a Waste 2.0', *World Bank Publ. - Books*, 2018, Accessed: Feb. 02, 2025. [Online]. Available: https://ideas.repec.org//b/wbk/wbpubs/30317.html.
34. 'World Development Indicators | DataBank'. https://databank.worldbank.org/id/23d06e56 (accessed Feb. 02, 2025).
35. 'Global Economic Data, Indicators, Charts & Forecasts'. https://www.ceicdata.com/en/ (accessed Feb. 04, 2025).
36. 'South Sudan - Agricultural Land (sq. Km) - 2025 Data 2026 Forecast 2011-2021 Historical'. https://tradingeconomics.com/south-sudan/agricultural-land-sq-km-wb-data.html (accessed Feb. 04, 2025).
37. 'Eritrea Population (2025) - Worldometer'. https://www.worldometers.info/world-population/eritrea-population/ (accessed Feb. 04, 2025).
38. 'Sudan - Global Forest Resources Assessment 2015 – Country Report', 2015, Accessed: Feb. 04, 2025. [Online]. Available: https://openknowledge.fao.org/handle/20.500.14283/az342e.
39. https://www.fao.org/aquastat/en/countries-and-basins/country-profiles (Accessed Feb. 04, 2025).
40. 'Nationally Determined Contributions Registry | UNFCCC'. https://unfccc.int/NDCREG (accessed Feb. 04, 2025).
41. 'Home | International Environmental Agreements (IEA) Database Project'. https://www.iea.ulaval.ca/en (accessed Feb. 04, 2025).
42. Manager, 'Global Material Flows Database', Jan. 2018, Accessed: Feb. 04, 2025. [Online]. Available: https://www.resourcepanel.org/global-material-flows-database.
43. D. Hoornweg, and P. Bhada-Tata, 'Altmetric – What a waste : a global review of solid waste management', 2012. https://worldbank.altmetric.com/details/3830788 (accessed Feb. 04, 2025).
44. G. Hutcheson and G. Hutcheson, 'Ordinary Least-Squares Regression', in *The SAGE Dictionary of Quantitative Management Research*, 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2011, pp. 225–228.
45. 'Housing Finance in Africa Yearbook - CAHF | Centre for Affordable Housing Finance Africa'. https://housingfinanceafrica.org/projects/housing-finance-yearbook/ (accessed Feb. 04, 2025).
46. 'Atlasocio.com | L'atlas sociologique mondial'. https://atlasocio.com/ (accessed Feb. 04, 2025).

47. U. N. United Nations Development Programme (UNDP), *Human Development Report 2019: Beyond Income, Beyond Averages, Beyond Today - Inequalities in Human Development in the 21st Century*, 1st ed. Bloomfield: United Nations Publications, 2019.
48. E. Nkiaka, U. T. Okpara, and M. Okumah, 'Food-energy-water security in sub-Saharan Africa: Quantitative and spatial assessments using an indicator-based approach', *Environ. Dev.*, vol. 40, p. 100655, Dec. 2021, https://doi.org/10.1016/j.envdev.2021.100655.
49. 'Energies renouvelables en Afrique : Enjeux, défis et opportunités', *Policy Center*. https://www.policycenter.ma/publications/energies-renouvelables-en-afrique-enjeux-d%C3%A9fis-et-opportunit%C3%A9s. (Accessed: Feb. 04, 2025).
50. S. J. Ergun, P. A. Owusu, and M. F. Rivas, 'Determinants of renewable energy consumption in Africa', *Environ. Sci. Pollut. Res.*, vol. 26, no. 15, pp. 15390–15405, May 2019, https://doi.org/10.1007/s11356-019-04567-7.
51. W. Beckerman, 'Economic growth and the environment: Whose growth? whose environment?', *World Dev.*, vol. 20, no. 4, pp. 481–496, Apr. 1992, https://doi.org/10.1016/0305-750X(92)90038-W.
52. M. Abid, 'Impact of economic, financial, and institutional factors on CO2 emissions: Evidence from Sub-Saharan Africa economies', *Util. Policy*, vol. 41, pp. 85–94, Aug. 2016, https://doi.org/10.1016/j.jup.2016.06.009.

APPENDIX

Appendix 1 Ranking of the African countries according to the CESDI

Rank	Country	CEFS	CEEA	CEER	CESDI
1	Gabon	0,636	0,795	0,584	0,671
2	Congo Republic	0,601	0,671	0,684	0,652
3	South Africa	0,266	0,655	0,710	0,543
4	Namibia	0,505	0,553	0,541	0,533
5	Seychelles	0,475	0,586	0,500	0,520
6	Mauritius	0,306	0,620	0,595	0,507
7	Botswana	0,474	0,425	0,552	0,484
8	Tunisia	0,271	0,644	0,528	0,481
9	Sao Tome and Principe	0,411	0,578	0,431	0,473
10	Egypt	0,248	0,596	0,553	0,466
11	Zimbabwe	0,257	0,574	0,563	0,465
12	Benin	0,257	0,548	0,587	0,464
13	Comoros	0,262	0,670	0,447	0,460
14	Morocco	0,229	0,613	0,521	0,454
15	Cameroon	0,267	0,670	0,417	0,451
16	Congo (RDC)	0,452	0,533	0,359	0,448
17	Eswatini	0,243	0,613	0,482	0,446
18	Gambia	0,347	0,615	0,374	0,445
19	Cabo Verde	0,275	0,598	0,427	0,433
20	Senegal	0,278	0,612	0,409	0,433
21	Kenya	0,104	0,673	0,478	0,418
22	Mozambique	0,187	0,637	0,427	0,417
23	Cote d'Ivoire	0,272	0,554	0,422	0,416
24	Ghana	0,321	0,549	0,373	0,414
25	Zambia	0,297	0,612	0,334	0,414
26	Algeria	0,189	0,545	0,505	0,413
27	Equatorial Guinea	0,190	0,408	0,639	0,412

28	Guinea	0,257	0,600	0,366	0,408
29	Liberia	0,339	0,556	0,283	0,393
30	Angola	0,173	0,530	0,474	0,392
31	Central African Republic	0,262	0,521	0,374	0,386
32	Burkina Faso	0,229	0,483	0,441	0,384
33	Mali	0,195	0,570	0,371	0,379
34	Malawi	0,301	0,518	0,314	0,378
35	Djibouti	0,231	0,453	0,441	0,375
36	Ethiopia	0,087	0,661	0,355	0,368
37	Tanzania	0,194	0,546	0,361	0,367
38	Sudan	0,086	0,556	0,444	0,362
39	Togo	0,092	0,626	0,339	0,352
40	Nigeria	0,127	0,479	0,445	0,350
41	Guinea-Bissau	0,385	0,336	0,317	0,346
42	Chad	0,081	0,545	0,403	0,343
43	Mauritania	0,197	0,408	0,422	0,342
44	Lesotho	0,186	0,500	0,338	0,341
45	Uganda	0,183	0,366	0,467	0,339
46	Rwanda	0,194	0,558	0,263	0,338
47	Madagascar	0,122	0,527	0,348	0,333
48	Libya	0,147	0,460	0,382	0,329
49	Eritrea	0,125	0,649	0,212	0,329
50	Somalia	0,173	0,553	0,239	0,322
51	Sierra Leone	0,231	0,507	0,223	0,320
52	Burundi	0,169	0,530	0,205	0,301
53	Niger	0,087	0,495	0,275	0,286
54	South Sudan	0,129	0,208	0,413	0,250

Appendix 2 Ranking of the African countries according to the CESDIaag

RANK	Country	CEFSaag	CEEAaag	CEERaag	CESDIaag
1	Ethiopia	0,515	0,619	0,559	0,564
2	Mauritius	0,672	0,449	0,518	0,546
3	Somalia	0,668	0,503	0,442	0,538
4	Eswatini	0,595	0,493	0,514	0,534
5	Seychelles	0,470	0,615	0,487	0,524
6	Morocco	0,594	0,476	0,491	0,521
7	Cabo Verde	0,636	0,529	0,384	0,516
8	Rwanda	0,525	0,636	0,380	0,514
9	Lesotho	0,671	0,549	0,320	0,513
10	Malawi	0,460	0,680	0,395	0,512
11	Comoros	0,469	0,502	0,563	0,511
12	Tunisia	0,639	0,489	0,391	0,506
13	Uganda	0,289	0,539	0,672	0,500
14	Kenya	0,505	0,556	0,433	0,498
15	Liberia	0,477	0,650	0,366	0,497
16	Guinea	0,493	0,534	0,465	0,497
17	Central African Republic	0,651	0,500	0,320	0,490

18	Botswana	0,534	0,510	0,425	0,490
19	Burundi	0,521	0,563	0,371	0,485
20	Zimbabwe	0,465	0,536	0,452	0,484
21	Zambia	0,442	0,589	0,418	0,483
22	South Africa	0,585	0,470	0,393	0,483
23	Sao Tome and Principe	0,517	0,519	0,407	0,481
24	Madagascar	0,475	0,522	0,445	0,481
25	Egypt	0,545	0,508	0,387	0,480
26	Chad	0,362	0,589	0,481	0,477
27	Benin	0,479	0,537	0,394	0,470
28	Sierra Leone	0,576	0,493	0,336	0,468
29	Guinea-Bissau	0,483	0,529	0,392	0,468
30	Namibia	0,501	0,472	0,427	0,467
31	Eritrea	0,544	0,561	0,290	0,465
32	Mozambique	0,440	0,563	0,382	0,462
33	Cote d'Ivoire	0,483	0,473	0,429	0,461
34	Tanzania	0,441	0,514	0,420	0,458
35	South Sudan	0,459	0,579	0,331	0,456
36	Djibouti	0,560	0,396	0,400	0,452
37	Congo Republic	0,482	0,530	0,339	0,450
38	Algeria	0,538	0,302	0,506	0,449
39	Mauritania	0,416	0,489	0,434	0,446
40	Ghana	0,521	0,379	0,436	0,445
41	Cameroon	0,448	0,477	0,410	0,445
42	Niger	0,360	0,551	0,422	0,444
43	Burkina Faso	0,417	0,470	0,445	0,444
44	Mali	0,428	0,496	0,406	0,443
45	Congo Democratic Republic	0,410	0,468	0,444	0,441
46	Gabon	0,452	0,467	0,401	0,440
47	Libya	0,657	0,566	0,094	0,439
48	Gambia	0,429	0,485	0,373	0,429
49	Senegal	0,411	0,432	0,444	0,429
50	Togo	0,305	0,571	0,408	0,428
51	Angola	0,401	0,485	0,376	0,421
52	Nigeria	0,365	0,464	0,419	0,416
53	Equatorial Guinea	0,304	0,477	0,467	0,416
54	Sudan	0,171	0,474	0,527	0,391