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A Re-Evaluation of How Well Each Country is Doing in Terms of Achieving The SDGs: An Objective Approach Based on Multi-Criteria-Decision-Analysis

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ABSTRACT

Adopting Agenda 2030, the UN issued a set of sustainable development report consisting of 17 goals. The indices created by these goals are beneficial in defining the position of a particular country across the years; however, it is relatively complex to compare its position to other countries. This is not just because it requires an extensive analysis but also because the weight of each goal must be different. It is hard to determine which goal is more important than the others, as it differs from one specialist to another. Then how should we determine the goal weights without falling into the trap of subjective suggestions? That is our question for this research paper. Therefore, we use the multiple-criteria decision-making approach (MCDM) in order to characterise each country's position more accurately. Doing so, we get diverse weights instead of just using the SDGs' arithmetical averages. Therefore, our findings show slightly different rankings than the UN's SDG report 2022.

Keywords: Multiple-criteria decision-making, Entropy, Aras, Sustainable Development Goals.

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INTRODUCTION

SUSTAINABLE DEVELOPMENT

A broad notion, "development" can be interpreted in many different ways, from the strictly economic to the more social and environmental. Within the development context sustainable development has gained the attention of economist and therefore policy makers. Sustainable development encapsulates multiple dimensions covering socio-economic, ecological, technical and ethical perspectives. When translating sustainability policies into practical action, it becomes crucial to address fundamental issues such as what aspects are to be sustained and for whose benefit. Sustainability issues inherently involve significant conflicts and tensions. In order to address these issues The General Assembly of United Nations endorsed the Sustainable Development Goals also known as SDGs. The 2030 Agenda for Sustainable Development consists of 17 SDGs focusing on the improvement of the overall situation in the world, at the UN Sustainable Development Summit in September 2015. Therefore, policy makers are forced to consider the sustainability and long-term economic, social, and environmental implications. These SDGs offer a framework for international development initiatives to realise a more sustainable and inclusive society by the year 2030. Here is a succinct description of each SDG in the table 1.

These goals emphasise the need for inclusive and sustainable economic growth, the eradication of poverty, the creation of jobs, innovation, and responsible consumption and production practises in order to provide a more sustainable future for all. However integrating social and environmental issues into financial decisions requires complex decision-making processes that require new methods and best practises.

A sophisticated decision-making process that considers various factors and trade-offs between objectives is necessary to achieve all the SDGs. The 2030 Agenda framework's implementation began in 2016. Since then, a growing number of recommendations, frameworks, methodological evaluations, and academic research on this topic have been published. The studies have shown quite a wide range of results that are contradictory due to the weaknesses of the assessment of the goals

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Table 1. SDGs' Descriptions

SDG	Description
SDG1: No Poverty	By encouraging inclusive economic growth, social safety programmes, and equal access to economic opportunities, the goal strives to end extreme poverty and lower overall poverty rates.
SDG2: No Hunger	This goal aims to end hunger, improve food security, and advance sustainable agriculture. It highligts the need for increased agricultural productivity, investment in rural infrastructure, and fair distributions of resources.
SDG3: Good Health and Well-Being	This goal focuses to ensure that everyone leads healthy lives and is in good well-being. It addresses issues including disease prevention, mental health, and healthcare access, placing emphasis on the significance of universal health coverage.
SDG4: Quality Education	This goal aspires to offer all people a quality education that is inclusive and egalitarian. It places a strong emphasis on expanding educational options, raising educational standards, and promoting lifelong learning.
SDG5: Gender Equality	This goal encourages gender equality and female empowerment by placing a strong emphasis on giving women and girls the same rights, opportunities, and involvement in economic activities, decision-making processes, and society at large.
SDG6: Clean Water and Sanitation	This goal focuses on ensuring that everyone has access to clean water and sufficient sanitary facilities. To assist sustainable water resource management, it addresses water shortages, water efficiency, and wastewater treatment.
SDG7: Affordable and Clean Energy	This goal aims to guarantee that everyone has access to affordable, dependable, and sustainable energy. It supports increased energy infrastructure, energy efficiency, and renewable energy sources.
SDG8: Decent Work and Economic Growth	This goal places a strong emphasis on full and productive employment, inclusive economic growth, and decent labour for all. It emphasises economic diversity, entrepreneurship, labour rights, and job development.
SDG9: Industry, Innovation and Infrastructure	The goal aims to promote inclusive and sustainable infrastructure development, industrialization, and innovation. It places a strong emphasis on spending money on infrastructure, advancing technology, and encouraging environmentally friendly business practises
SDG10: Reduced Inequalities	This goal addresses inequities both inside and between nations. It emphasises lowering income inequality, fostering social inclusion, and guaranteeing equitable chances for everyone, especially marginalised and vulnerable groups.
SDG11: Sustainable Cities and Communities	The focus of this goal is on building inclusive, secure, robust, and sustainable urban communities. It encourages access to affordable housing, efficient urban infrastructure, and sustainable urban development.
SDG12: Responsible Consumption and Production	The goal promotes environmentally friendly patterns of consumption and production. It places a strong emphasis on resource efficiency, waste minimization, environmentally friendly purchasing, and sustainable use of natural resources.
SDG13: Climate Action	This goal aims to combat the effects of climate change. It advocates for catastrophe preparedness procedures, adaption tactics, and resilience building.
SDG14: Life Below Water	This goal is concerned with protecting and utilising marine resources and oceans sustainably. The protection of coastal habitats and challenges like marine pollution and overfishing are covered.
SDG15: Life on Land	The goal encourages the preservation, restoration, and sustainable use of terrestrial ecosystems. Deforestation, biodiversity loss, and sustainable land management techniques are all covered.
SDG16: Peace, Justice and Strong Institutions	Access to justice, effective and responsible institutions, and peaceful and inclusive societies are the three pillars of this goal. It deals with matters like lessening violence, battling corruption, and advancing the rule of law.
SDG17: Partnerships for the Goals	This goal highlights the value of international collaboration for sustainable development. To mobilise resources and spread knowledge to accomplish the SDGs, it calls for more cooperation between governments, corporations, civil society, and other stakeholders.

Source: https://unstats.un.org/sdgs/report/2020/#sdg-goals. Accessed: 10/03/2023

(Stafford et al., 2017). While some studies only focus on the achievement of a particular SDG, others take few of them. Also, in some studies researchers study a group of countries or one single country. (Lim et al. 2016; Stafford-Smith et al. 2017; Schwerhoff and Sy 2017; Fullman et al, 2017; Salvia et al. 2019; Sims et al. 2019; Allen et al. 2020.).

We don't often see all countries are taken into consideration at the same time. In contrast to earlier studies, which frequently concentrated on particular groups of countries, our goal is to include every nation at once for all SDGs. The traditional SDG index can produce erroneous and possibly deceptive country rankings because it computes simple arithmetic averages for each SDG. In contrast, our strategy makes use of Multi-Criteria Decision Making (MCDM) methodologies, which modify the weights given to each goal according on how important they are. We arrive at a subjective ranking for each nation using these techniques, which contrasts with the ranks provided in UN publications. We reevaluate the goals and their relative importance based on weights determined using the Entropy technique. We then include these results into the ARAS methodology to create a new rating of countries that more accurately represents how well they are doing in terms of achieving the SDGs.

By using these techniques, we hope to provide a more thorough and nuanced knowledge of how nations are doing in terms of achieving the SDGs, while also supporting a more accurate evaluation of nations' successes in sustainable development and taking into account the various relevance of each objective.

THE MULTI CRITERIA DECISION MAKING (MCDM) AND ITS APPLICATIONS IN THE SDG CONTEXT

Within a long-term perspective, decision-making procedures should concurrently consider decisions' effects on the economy, society, and environment. It requires complex decision-making processes, where new ideas and best practises must be created and put into practise, to make judgements that are deeper than the financial aspect by combining social and environmental issues.

Due to its subjective criterion weighting analysis, the MCDM method is the most prominent decision-making instrument. MCDM evaluates a set of alternatives based on multiple, typically contradictory decision criteria (Ishizaka & Nemery, 2013; Greco et al., 2016). Multi-Criteria Decision Analysis (MCDA) is a technique used to manage difficult and complicated policy decision-making issues. It recognises that conflicts frequently arise as a result of diverse objectives of actors in an economy. MCDA intends to resolve these conflicts by organising the interests of these actors into practical and quantifiable criteria. It allows for the aggregation of group preferences across multiple criteria and provides a framework for evaluating the performance of alternative policy options based on these criteria. In essence, MCDA facilitates the making of well-informed decisions by systematically weighing multiple perspectives and objectives (Brett et. al. 2019). A selection of the pertinent research papers are mentioned in this area.

MCDM methods have demonstrated their usefulness in assisting decision-makers in assigning criteria weighs and prioritize goals in various geographical and cultural contexts particularly under uncertainty (Ringius et al. 1998; Bell et al., 2001; Gamboa, 2006; Garmendia and Stagl, 2010).

The literature suggests utilization of MCDM methods enhances the adaptability and precision of decision-making processes when prioritizing of SDGs to be included in a country's 2030 Agenda. Karaşan and Kahraman (2018) created the Interval-Valued Neutrosophic EDAS method. The method was used to select the SDGs in which Turkey should begin investing in the context of the national 2030 Agenda. Oliveira et al. (2019) presented a systemic and contextual framework designed to prioritize SDGs for the Brazilian 2030 Agenda. Their approach integrated two fuzzy MCDM methods (fuzzy AHP and fuzzy TOPSIS) along with prospective structural analysis (PSA) and network theory tools. In another study, Resce and Schiltz (2020) developed a MCDM approach to assess the performance of European countries in achieving the SDGs. They employed the Hierarchical Stochastic Multicriteria Acceptability Analysis (HSMAA) method. According to Benítez and Liern (2020), introducing the new unweighted TOPSIS (uwTOPSIS) method propose a solution to address the challenge of assigning weights to sustainability criteria when ranking alternatives related to the SDGs.

Researchers use MCDM techniques to cope with the assessment of a set of alternatives in terms of numerous, frequently competing, decision criteria since the techniques give decision-makers the flexibility to take decisions while simultaneously taking all the criteria and objectives into account (Zavadskas and Turskis, 2011). It is especially helpful in the context of the SDGs since it enables simultaneous consideration of the impact of alternatives on the economy, society, and environment throughout the decision-making process. By using these techniques, it is possible to reach a consensus and make a more solid and long-lasting conclusion.

In accordance with a set of decision criteria, MCDM aims to offer a choice, rating, description, classification, and sorting of alternatives. There are various methods to perform MCDM analysis such as ARAS, TOPSIS, COCOSO, AHP/ANP, ELECTRE, PROMETHEE, and MAUT (Stanujkic et. al., 2020). The focus in this study is mostly on Entropy based ARAS and TOPSIS.

The main purpose of our study is to evaluate all SDG goals and all the countries at the same time employing a Multi-Criteria Decision-Making approach, which consists of entropy, ARAS and TOPSIS methods. By doing this, we are able to evaluate the SDGs objectively because the entropy technique weights each goal in accordance with its significance without the need for an outside, subjective intervention. Depending on the weight of the SDGs, the ranking of the countries will be more straightforward and more reliable. We propose the application of the hybrid model based on the Entropy and ARAS methods.

DATA AND METHODOLOGY

The 17 indicators pertaining to the 17 SDGs for the years 2002–2021 are introduced for the purposes of illustrating and evaluating the applicability of the suggested hybrid model. To exclude the outliers, the evaluation was conducted by removing the countries with scores equal to 0 and 100[1]. We, as well, run the analysis excluding some[2] of the SDGs in order to include all countries. Hence, we have two different data set one having all SDGs but excluding the countries with outliers, and, the other one with all countries excluding the SDGs with outliers.

We analyse each of the aforementioned years separately, averaging 5 years. Additionally, we split the time period in half and provide the average results for the first ten years and the last ten years. For the sake of presenting a brief -and easy to read- study we demonstrated the computational procedure only for data of five years averages. The results of other sets are stated verbally.[3]

Entropy Method

Entropy was first proposed by Rudolf Clausius in 1865 and is referred to as a criterion of disorder and dispersion in thermodynamics. Entropy, the second rule of thermodynamics, asserts succinctly that all systems left to their own devices and subject to the natural forces of the universe will eventually degenerate and become disordered. Law of entropy is expressed as the most economic among all other laws of physics (Georgescu-Roegen, 1971). Moreover, the method contributed notably to the economics science by emphasising the essentiality of including ecological issues in the field of economic growth in recent years entropy economics also has been helpful in econometric methods (Jakimowicz, 2020).

Shannon (1948) gave this idea a new meaning and named it information entropy. Therefore now entropy is defined as a measure of the uncertainty connected to random variables, according to information theory. (Bakir and Atalik, 2018; Zhang et. al., 2011). Without relying on the decision-makers' subjective assessments of the criteria's relative relevance, the entropy technique uses the values of the alternatives to determine the weights of the criteria in an objective manner. (Karaatli, 2016). The following are the stages in the process used to calculate the weights for the objective criteria (Zhu and Tian, 2020; Arsu, 2021; Karami and Johansson, 2014; Shemshadi et al.,2011):

1st stage: The decision matrix is constructed at this stage. D is a representation of the decision matrix and contains the elements x_{ij} (the value of the i th alternative according to the j th criterion). Equation (1) describes the Decision matrix.

$$H(Q_m) = -\sum_k p_{mk} \log(p_{mk}). \quad (1)$$

where m denotes number of alternatives and, n is the number of criteria.

2nd stage: The values taken from the different units are normalized in this stage. Each value is standardized to take a value between [0, 1] throughout the normalization procedure. For normalization, we use Equation (2).

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad \forall\ i, j\ için \quad (2)$$

[1] Azerbaijan, Burundi, Burkina Faso, Brunei Darussalam, Botswana, Central African Republic, Congo Dem. Rep., Switzerland, Djibouti, Estonia, Kazakhstan, Luxembourg, Madagascar, Malaysia, Namibia, Niger, Qatar, Russian Federation, Somalia, South Sudan, Chad, Thailand, Uruguay, South Africa are excluded from the study.

[2] The excluded SDGs are: SDG 1, SDG 4, SDG 9, SDG 10, SDG 13

[3] Available upon request from the authors of this paper.

3rd stage: At this stage, entropy values regarding the criteria's () and differentiation degrees () are determined. Entropy values are calculated using Equation (3), and degrees of differentiation are calculated using Equation (4).

$$e_{ij} = -\frac{1}{\ln(m)}\sum_{j=1}^{n}[p_{ij}\,.\ln\,(p_{ij})] \qquad \forall\, i, j\; için \quad (3)$$

$$d_j = 1 - e_{ij} \qquad \forall\, j\; için \quad (4)$$

4th stage:

We finally determine the weights of the criteria using the Equation (5)

$$w_{ij} = \frac{d_j}{\sum_{j=1}^{n} d_j} \qquad \forall\, j\; için \quad (5)$$

Entropy Method Results: Weighing the Criteria

In this section we apply the stages of entropy to obtain the Entropy criteria weights to apply in ARAS method. We first calculate the decision matrix, then the normalised matrix. Thirdly we determine the entropy values regarding the criteria's) and differentiation degrees to obtain the Entropy criteria weights.

1. Stage: Decision Matrix[4]

The decision matrix constructed first that contains the elements of presented in Table 1. The values are calculated for the first five years' average of our data set to set an example.

2. Stage: Normalisation of decision matrix

Normalized values [0, 1] are obtained by dividing each value in the decision matrix by the sum of their corresponding column. Table 2 demonstrates the normalised decision matrix for a few countries for the first five years' average.

3. Stage: Determining the entropy values regarding the criteria's (ej) and differentiation degrees (dj)

Initially, each value in the normalised decision matrix is multiplied by its natural logarithm to determine the entropy values (ej) of the criteria shown in the Table 3. Using the results from equation-3, entropy values are calculated. In this case, m is the number of alternatives (countries), therefore, we obtain $ln(m) = ln(140) = 0{,}2024$. Then the differentiation degrees are found using the equation $dj= 1-ej$.

Table 1. Decision Matrix.

Code	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
AFG	91,4171	38,4163	22,2085	1,6330	20,8603	33,3091	33,3433	33,2753	2,0869
ALB	94,3185	42,6799	75,0475	75,9987	38,3408	70,4172	73,3787	54,6064	5,1634
DZA	94,4630	49,1057	71,6182	57,0913	30,0288	61,3807	60,4940	56,5526	9,6108
AGO	25,1790	48,9669	24,1958	38,9058	44,0592	46,2678	41,5413	57,2963	0,8303
ARG	97,1360	68,3199	79,2473	92,9593	74,0689	77,1719	69,2639	58,6727	15,8195
…	…	…	…	…	…	…	…	…	…
YEM	91,7239	40,5514	40,7646	33,7522	6,5354	29,0258	31,2856	51,0588	5,7139
ZMB	7,2175	55,7883	22,0321	42,2349	46,2399	47,5133	55,5481	48,3635	1,9807
ZWE	28,6597	42,6293	22,4813	60,2485	60,5025	50,1970	59,6492	56,9148	5,8709
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	80,8852	26,9864	97,7586	99,2130	58,9315	51,8360	44,8566	35,6560	
ALB	83,0793	78,2525	88,3580	86,0660	33,9878	67,8200	69,3695	59,7019	
DZA	97,0150	72,7997	91,8681	87,3493	69,7909	53,9464	67,1352	57,0520	
AGO	15,4930	32,8651	95,2543	94,0143	66,5728	66,5036	43,1384	54,0385	
ARG	34,5328	73,4971	83,9506	87,1123	63,8611	56,9992	59,3441	55,2916	
…	…	…	…	…	…	…	…	…	
YEM	69,1090	50,0116	96,7554	96,5875	64,1650	42,5525	45,4307	64,1881	
ZMB	19,0422	61,2384	96,4269	98,0163	66,1295	69,4888	49,5617	46,1346	
ZWE	33,9810	72,6315	95,9196	96,9247	66,1295	72,2076	46,3157	38,0435	

Source: Author's calculations based on Sachs et.al. 2020. The values are obtained five-year averages from 2002 to 2006.

[4] The tables with the whole country set is available upon request from the authors.

Table 2. Normalised Decision Matrix.

Code	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
AFG	0,0091	0,0048	0,0026	0,0002	0,0029	0,0037	0,0039	0,0037	0,0007
ALB	0,0094	0,0053	0,0087	0,0079	0,0054	0,0079	0,0085	0,0060	0,0017
DZA	0,0094	0,0061	0,0083	0,0060	0,0042	0,0069	0,0070	0,0062	0,0032
AGO	0,0025	0,0061	0,0028	0,0041	0,0062	0,0052	0,0048	0,0063	0,0003
ARG	0,0097	0,0085	0,0092	0,0097	0,0104	0,0086	0,0080	0,0065	0,0052
…	…	…	…	…	…	…	…	…	…
YEM	0,0091	0,0050	0,0048	0,0035	0,0009	0,0033	0,0036	0,0056	0,0019
ZMB	0,0007	0,0069	0,0026	0,0044	0,0065	0,0053	0,0065	0,0053	0,0007
ZWE	0,0029	0,0053	0,0026	0,0063	0,0085	0,0056	0,0069	0,0063	0,0019
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	0,0097	0,0028	0,0082	0,0088	0,0068	0,0060	0,0049	0,0046	
ALB	0,0100	0,0081	0,0074	0,0076	0,0039	0,0078	0,0075	0,0076	
DZA	0,0116	0,0076	0,0077	0,0077	0,0081	0,0062	0,0073	0,0073	
AGO	0,0019	0,0034	0,0080	0,0083	0,0077	0,0077	0,0047	0,0069	
ARG	0,0041	0,0077	0,0070	0,0077	0,0074	0,0066	0,0065	0,0071	
…	…	…	…	…	…	…	…	…	
YEM	0,0083	0,0052	0,0081	0,0085	0,0074	0,0049	0,0049	0,0082	
ZMB	0,0023	0,0064	0,0081	0,0087	0,0077	0,0080	0,0054	0,0059	
ZWE	0,0041	0,0076	0,0081	0,0086	0,0077	0,0083	0,0050	0,0049	

Source: Authors' calculation based on Sachs et.al. 2020.

Table 3. Entropy values (ej) and Differentiation Degrees (dj)

Code	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
AFG	-0,0428	-0,0255	-0,0154	-0,0015	-0,0172	-0,0209	-0,0215	-0,0205	-0,0050
ALB	-0,0439	-0,0277	-0,0415	-0,0383	-0,0282	-0,0382	-0,0406	-0,0307	-0,0109
DZA	-0,0439	-0,0310	-0,0400	-0,0305	-0,0231	-0,0342	-0,0348	-0,0316	-0,0182
AGO	-0,0150	-0,0310	-0,0166	-0,0223	-0,0316	-0,0273	-0,0257	-0,0320	-0,0022
ARG	-0,0449	-0,0404	-0,0433	-0,0449	-0,0477	-0,0411	-0,0388	-0,0326	-0,0274
…	…	…	…	…	…	…	…	…	…
YEM	-0,0429	-0,0266	-0,0254	-0,0199	-0,0064	-0,0186	-0,0204	-0,0291	-0,0118
ZMB	-0,0052	-0,0344	-0,0153	-0,0239	-0,0328	-0,0279	-0,0325	-0,0279	-0,0048
ZWE	-0,0167	-0,0277	-0,0156	-0,0319	-0,0407	-0,0291	-0,0344	-0,0318	-0,0121
ej	0,9763	0,9963	0,9842	0,9813	0,9874	0,9926	0,9904	0,9972	0,9023
dj	0,0237	0,0037	0,0158	0,0187	0,0126	0,0074	0,0096	0,0028	0,0977
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	-0,0450	-0,0165	-0,0394	-0,0415	-0,0341	-0,0306	-0,0260	-0,0246	
ALB	-0,0459	-0,0392	-0,0364	-0,0371	-0,0218	-0,0379	-0,0369	-0,0372	
DZA	-0,0518	-0,0370	-0,0375	-0,0375	-0,0390	-0,0316	-0,0359	-0,0359	
AGO	-0,0117	-0,0194	-0,0386	-0,0398	-0,0376	-0,0373	-0,0252	-0,0344	
ARG	-0,0227	-0,0373	-0,0349	-0,0375	-0,0363	-0,0330	-0,0325	-0,0350	
…	…	…	…	…	…	…	…	…	
YEM	-0,0397	-0,0274	-0,0391	-0,0407	-0,0365	-0,0261	-0,0262	-0,0394	
ZMB	-0,0139	-0,0322	-0,0390	-0,0411	-0,0374	-0,0386	-0,0282	-0,0303	
ZWE	-0,0224	-0,0369	-0,0388	-0,0408	-0,0374	-0,0398	-0,0266	-0,0259	
ej	0,977498	0,993377	0,997636	0,990757	0,997725	0,996277	0,995999	0,99492	
dj	0,022502	0,006623	0,002364	0,009243	0,002275	0,003723	0,004001	0,00508	

Source: Authors' calculation based on Sachs et.al. 2020.

Table 4. Criterion Weights

Weight	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
wj	0,0957	0,0151	0,0638	0,0755	0,0508	0,0297	0,0389	0,0113	0,3941
% Values	9,57	1,51	6,38	7,55	5,08	2,97	3,89	1,13	39,41
Weight	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	SDG 16	SDG 17	
wj	0,0908	0,0267	0,0095	0,0373	0,0092	0,0150	0,0161	0,0205	
% Values	9,08	2,67	0,95	3,73	0,92	1,5	1,61	2,05	

4. Stage: Determining the Entropy criteria weights

Each degree of differentiation value is divided by the overall differentiation value to produce criterion weights.

The Entropy technique determines that Goal 9 (39.41%) is the most significant criterion, as shown in Table 4. This criterion is followed by criteria of Goals 1, 10, 4, 3, 5, 7, 13, 6, 11, 17, 16, 2, 15, 8, 12 and 14 respectively. Same results are obtained for each 5-year averages.[5]

ARAS Method

The ARAS (Additive Ratio Assessment) method, one of the multi-criteria decision-making techniques, was first introduced to the literature by Zavadskas and Turskis in 2010.

Using a variety of criteria, this method ranks the decision alternatives according to the utility function value. Taking a variety of criteria into account, this method ranks the decision alternatives according to the utility function value.

According to ARAS method, the relative effects of the weights and values of the criteria are directly related to the utility function used to calculate the relative efficacy of an alternative in the decision problem. The ARAS method is based on a set of clear-cut mathematical calculations. Despite being a novel approach, it is clear that this technique makes it simple to compare the alternatives and is widely used in the literature (Aras and Yildirim, 2020).

The following are the steps of the ARAS method (Yildirim, 2015; Ayçin, 2019; Zavadskas et. al., 2010):

1st stage: The decision matrix is set at this step as we did in the Entropy step. Decision matrix is denoted by X and contains the elements X_{ij} (the value of the th alternative according to the th criterion). The decision matrix is represented in Equation (6).

$$X = [x_{ij}]_{mxn} \qquad i = 0,1,2,\ldots,m \;;\; j = 1,2,3,\ldots,n \tag{6}$$

Where X_{0j} denotes optimal value of the jth criterion, m is the number of alternatives and, n is the number of criteria.

If a criterion's optimal value is unknown, Equation (7) is applied if it is a benefit criterion, and Equation (8) is applied if it is a cost criterion.

$$x_{0j} = max_i x_{ij} \tag{7}$$

$$x_{0j} = max_i x_{ij} \tag{8}$$

2nd stage: The values that are derived from various units are normalised at this stage. As a result, each value is standardised to take a value between [0, 1].

In the normalisation process Equation (9) is employed for the benefit criteria, and Equation (10) is applied for the cost criteria.

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \tag{9}$$

$$\bar{x}_{ij} = \frac{1/x_{ij}}{\sum_{i=0}^{m} x_{ij}} \tag{10}$$

By replacing the new values derived from equation (9) and equation (10)'dan into equation (11) we obtain normalised decision matrix.

$$\bar{X} = [\bar{x}_{ij}]_{mxn} \qquad i = 0,1,2,\ldots,m \;;\; j = 1,2,3,\ldots,n \tag{11}$$

3rd stage: Normalised decision matrix is weighted at this stage. The values of the weighted normalised decision matrix are generated by using the criterion weights in the equation (12) obtained by the entropy method. In Equation (12), weighted normalised decision matrix values are produced using the criterion weights acquired by the entropy method.

$$\hat{x}_{ij} = \bar{x}_{ij} \,.\, w_j \tag{12}$$

We generate normalised weighted decision matrix by entering the values obtained from equation (12) into equation (13).

$$\hat{X} = [\hat{x}_{ij}]_{mxn} \qquad i = 0,1,2,\ldots,m \;;\; j = 1,2,3,\ldots,n \tag{13}$$

[5] The results can be found in the appendix.

4th stage: At this stage, the optimality function values for each alternative are determined by substituting the weighted normalised decision matrix values in Equation (14).

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij} \qquad i = 0,1,2,\dots,m \ ; \ \ j = 1,2,3,\dots,n \qquad (14)$$

5th stage: Now, we can calculate the utility degree by proportioning the optimality function value of a decision alternative to the optimality function value of the best alternative. The utility degree is determined using equation (15).

$$K_i = \frac{S_i}{S_0} \qquad i = 0,1,2,\dots,m \qquad (15)$$

The utility function takes values between [0, 1]. Therefore, we are able to rank the alternative performances from best to worst.

Aras Method Results: Re-Ranking the Countries

1. Stage: Decision Matrix

The aspects of the criteria and the optimal values are determined upon creating the decision matrix demonstrated in the Table 5. In this case, all are benefit criterion. The optimal value is equal to the maximum value of the relevant criterion for benefit-criteria, and the minimum value of the relevant criterion for cost-criteria.

2. Stage: Normalisation of decision matrix

Table 6 depicts each value in the decision matrix, including the optimal value, is divided by the sum of the values in its column to produce the normalised values [0, 1].

3.stage: Weighted Normalised Decision Matrix

We multiply the criterion weights generated by Entropy method by normalised matrix, in order to produce weighted decision matrix shown in the Table 7.

Table 5. Decision matrix.

Code	**SDG 1**	**SDG 2**	**SDG 3**	**SDG 4**	**SDG 5**	**SDG 6**	**SDG 7**	**SDG 8**	**SDG 9**
AFG	91,4171	38,4163	22,2085	1,633	20,8603	33,3091	33,3433	33,2753	2,0869
ALB	94,3185	42,6799	75,0475	75,9987	38,3408	70,4172	73,3787	54,6064	5,1634
DZA	94,463	49,1057	71,6182	57,0913	30,0288	61,3807	60,494	56,5526	9,6108
AGO	25,179	48,9669	24,1958	38,9058	44,0592	46,2678	41,5413	57,2963	0,8303
ARG	97,136	68,3199	79,2473	92,9593	74,0689	77,1719	69,2639	58,6727	15,8195
…	…	…	…	…	…	…	…	…	…
YEM	91,7239	40,5514	40,7646	33,7522	6,5354	29,0258	31,2856	51,0588	5,7139
ZMB	7,2175	55,7883	22,0321	42,2349	46,2399	47,5133	55,5481	48,3635	1,9807
ZWE	28,6597	42,6293	22,4813	60,2485	60,5025	50,197	59,6492	56,9148	5,8709
Optimal	99,9405	82,5810	91,9784	99,6663	90,3751	94,8937	98,8856	90,8171	90,0051
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	80,8852	26,9864	97,7586	99,213	58,9315	51,836	44,8566	35,656	
ALB	83,0793	78,2525	88,358	86,066	33,9878	67,82	69,3695	59,7019	
DZA	97,015	72,7997	91,8681	87,3493	69,7909	53,9464	67,1352	57,052	
AGO	15,493	32,8651	95,2543	94,0143	66,5728	66,5036	43,1384	54,0385	
ARG	34,5328	73,4971	83,9506	87,1123	63,8611	56,9992	59,3441	55,2916	
…	…	…	…	…	…	…	…	…	
YEM	69,109	50,0116	96,7554	96,5875	64,165	42,5525	45,4307	64,1881	
ZMB	19,0422	61,2384	96,4269	98,0163	66,1295	69,4888	49,5617	46,1346	
ZWE	33,981	72,6315	95,9196	96,9247	66,1295	72,2076	46,3157	38,0435	
Optimal	100,0000	94,3721	98,7729	99,2663	83,7532	92,6512	94,5207	100,0000	

Source: Authors' calculation based on Sachs et.al. 2020.

Table 6. Normalised Decision Matrix

Code	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
AFG	0,0090	0,0047	0,0026	0,0002	0,0029	0,0037	0,0038	0,0036	0,0007
ALB	0,0093	0,0052	0,0087	0,0078	0,0053	0,0078	0,0084	0,0060	0,0017
DZA	0,0093	0,0060	0,0083	0,0059	0,0042	0,0068	0,0069	0,0062	0,0031
AGO	0,0025	0,0060	0,0028	0,0040	0,0061	0,0051	0,0048	0,0062	0,0003
ARG	0,0096	0,0084	0,0091	0,0096	0,0103	0,0086	0,0080	0,0064	0,0051
…	…	…	…	…	…	…	…	…	…
YEM	0,0090	0,0050	0,0047	0,0035	0,0009	0,0032	0,0036	0,0056	0,0018
ZMB	0,0007	0,0068	0,0025	0,0044	0,0064	0,0053	0,0064	0,0053	0,0006
ZWE	0,0028	0,0052	0,0026	0,0062	0,0084	0,0056	0,0068	0,0062	0,0019
Optimal	0,0099	0,0101	0,0106	0,0103	0,0126	0,0105	0,0114	0,0099	0,0288
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	0,0096	0,0028	0,0081	0,0087	0,0068	0,0059	0,0048	0,0045	
ALB	0,0098	0,0081	0,0074	0,0075	0,0039	0,0077	0,0075	0,0075	
DZA	0,0115	0,0075	0,0076	0,0077	0,0080	0,0061	0,0072	0,0072	
AGO	0,0018	0,0034	0,0079	0,0082	0,0076	0,0076	0,0046	0,0068	
ARG	0,0041	0,0076	0,0070	0,0076	0,0073	0,0065	0,0064	0,0070	
…	…	…	…	…	…	…	…	…	
YEM	0,0082	0,0052	0,0081	0,0085	0,0074	0,0049	0,0049	0,0081	
ZMB	0,0023	0,0063	0,0080	0,0086	0,0076	0,0079	0,0053	0,0058	
ZWE	0,0040	0,0075	0,0080	0,0085	0,0076	0,0082	0,0050	0,0048	
Optimal	0,0119	0,0097	0,0082	0,0087	0,0096	0,0106	0,0102	0,0126	

Source: Authors' calculation based on Sachs et.al. 2020. The values are constructed for the 5 years average of 2002 and 2006. We calculate the normalised decision matrix for all 5 years averages from 2002 to 2021.

Table 7. Weighted normalised decision matrix.

Code	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9
AFG	0,000863	0,000071	0,000163	0,000013	0,000148	0,000110	0,000149	0,000041	0,000263
ALB	0,000890	0,000079	0,000552	0,000592	0,000271	0,000232	0,000327	0,000067	0,000652
DZA	0,000892	0,000091	0,000527	0,000445	0,000212	0,000202	0,000270	0,000070	0,001213
AGO	0,000238	0,000091	0,000178	0,000303	0,000312	0,000153	0,000185	0,000071	0,000105
ARG	0,000917	0,000126	0,000583	0,000725	0,000524	0,000254	0,000309	0,000072	0,001997
…	…	…	…	…	…	…	…	…	…
YEM	0,000866	0,000075	0,000300	0,000263	0,000046	0,000096	0,000140	0,000063	0,000721
ZMB	0,000068	0,000103	0,000162	0,000329	0,000327	0,000157	0,000248	0,000060	0,000250
ZWE	0,000271	0,000079	0,000165	0,000470	0,000428	0,000166	0,000266	0,000070	0,000741
Optimal	0,000944	0,000153	0,000676	0,000777	0,000639	0,000313	0,000441	0,000112	0,011364
Code	**SDG 10**	**SDG 11**	**SDG 12**	**SDG 13**	**SDG 14**	**SDG 15**	**SDG 16**	**SDG 17**	
AFG	0,000870	0,000074	0,000078	0,000324	0,000062	0,000089	0,000078	0,000092	
ALB	0,000894	0,000215	0,000070	0,000281	0,000036	0,000116	0,000121	0,000155	
DZA	0,001044	0,000200	0,000073	0,000285	0,000074	0,000092	0,000117	0,000148	
AGO	0,000167	0,000091	0,000076	0,000307	0,000070	0,000114	0,000075	0,000140	
ARG	0,000371	0,000202	0,000067	0,000284	0,000067	0,000098	0,000103	0,000143	
…	…	…	…	…	…	…	…	…	
YEM	0,000743	0,000138	0,000077	0,000315	0,000068	0,000073	0,000079	0,000166	
ZMB	0,000205	0,000169	0,000077	0,000320	0,000070	0,000119	0,000086	0,000119	
ZWE	0,000366	0,000200	0,000076	0,000316	0,000070	0,000124	0,000080	0,000098	
Optimal	0,001076	0,000260	0,000078	0,000324	0,000088	0,000159	0,000164	0,000259	

Source: *Authors' calculation based on Sachs et.al. 2020.*

Table 8. Percentage weights of SDGs

2002-2006	%weight	2007-2011	%weight	2012-2016	%weight	2017-2021	%weight
SDG 9	39	SDG 9	39	SDG 9	32	SDG 9	25
SDG 1	10	SDG 1	11	SDG 1	11	SDG 10	14
SDG 10	9	SDG 10	9	SDG 10	11	SDG 1	12
SDG 4	8	SDG 4	7	SDG 4	6	SDG 4	6
SDG 3	6	SDG 3	6	SDG 3	6	SDG 3	5
SDG 5	5	SDG 5	5	SDG 13	5	SDG 13	5
SDG 7	4	SDG 13	4	SDG 5	5	SDG 5	5
SDG 13	4	SDG 7	4	SDG 7	4	SDG 11	4
SDG 6	3	SDG 6	3	SDG 11	4	SDG 7	4
SDG 11	3	SDG 11	3	SDG 6	3	SDG 6	3
SDG 17	2	SDG 17	2	SDG 17	3	SDG 17	3
SDG 16	2	SDG 15	2	SDG 15	2	SDG 16	3
SDG 2	2	SDG 16	2	SDG 16	2	SDG 15	3
SDG 15	2	SDG 2	1	SDG 2	2	SDG 2	2
SDG 8	1	SDG 8	1	SDG 8	2	SDG 8	2
SDG 12	1	SDG 12	1	SDG 12	1	SDG 12	2
SDG 14	1	SDG 14	1	SDG 14	1	SDG 14	2

Source: Authors' calculation based on normalised decision matrix.

Table 8 shows how certain SDGs are weighted in terms of percentages. The coloration depicts how heavily each SDG is weighted. The table shows that the weight of SDG9 -industry, innovation and infrastructure- has dropped over decades. SDG14, which focuses on life below water, hasn't gained much significance throughout the years. The weight doesn't necessarily

4. Stage: Optimality Function – Utility Degree and Ranking

First the values of the optimality utility function (Si) are calculated for each decision alternative using Equation 14. Then utility degree values ($K_{i)}$ are determined using equation (15)[6].

Finally, we rank the countries based on the utility degrees. In Table 9, we compare the results of the Entropy-ARAS technique with the rankings found in the UN SDG 2022 report. In the first 5 years average Australia, Korea, Singapore, Israel, USA are not in the first 20 of the new list. Likewise, the report's list omits Slovenia, Hungary, Czech Republic, Latvia. And the rest of the countries are in the different places in the list. Looking at the last 20 countries for the first 5 years average in the table 10 we can observe that Malawi, Uganda, Ethiopia, Sub-Saharan Africa, Mauritania aren't included in the UN report's list. On the other hand, Gambia, Cote d'Ivoire, Papua New Guinea, Oceania, Rwanda actually ranked better according to the new list.

ROBUSTNESS ANALYSIS

Rankings derived using the TOPSIS and ARAS methods based on Entropy criterion weights, provide similar outcomes. Table 11 demonstrates the Spearman's Rank correlation coefficient between the ranks obtained using the two methods.

The correlation is quite strong between the results obtained by ARAS and TOPSIS methods and significant at the 1% significance level.

6 Table A.III. 1 in Appendix A.III demonstrates the optimality function values (Si) and utility degree values (Ki).

Table 9. Comparison of country rankings based on UN 2030 report and Entropy-ARAS method.

2002-2006				2007-2011				2012-2016				2017-2021			
UN report		**Entropi-ARAS**		**UN report**		**Entr-pi-ARAS**		**UN report**		**Entropi-ARAS**		**UN report**		**Entropi-ARAS**	
SWE	1	1	SWE	SWE	1	1	SWE	FIN	1	1	SWE	FIN	1	1	DNK
NOR	2	2	FIN	FIN	2	2	FIN	SWE	2	2	DNK	DNK	2	2	SWE
JPN	3	3	DNK	DNK	3	3	DNK	DNK	3	3	FIN	SWE	3	3	FIN
FIN	4	4	NOR	NOR	4	4	JPN	NOR	4	4	KOR	NOR	4	4	AUT
DNK	5	5	AUT	AUT	5	5	KOR	AUT	5	5	NOR	DEU	5	5	NOR
NLD	6	6	NLD	IRL	6	6	NOR	DEU	6	6	JPN	AUT	6	6	DEU
AUS	7	7	DEU	DEU	7	7	NLD	GBR	7	7	DEU	FRA	7	7	BEL
CAN	8	8	IRL	NLD	8	8	DEU	IRL	8	8	NLD	GBR	8	8	NLD
KOR	9	9	GBR	GBR	9	9	AUS	FRA	9	9	AUT	IRL	9	9	FRA
DEU	10	10	JPN	JPN	10	10	SGP	NLD	10	10	BEL	POL	10	10	KOR
GBR	11	11	FRA	FRA	11	11	AUT	SVN	11	11	FRA	CZE	11	11	ISL
SGP	12	12	ISL	BEL	12	12	GBR	BEL	12	12	GBR	SVN	12	12	JPN
ISR	13	13	CAN	ESP	13	13	IRL	CZE	13	13	AUS	NLD	13	13	GBR
USA	14	14	BEL	CZE	14	14	FRA	JPN	14	14	IRL	LVA	14	14	ESP
IRL	15	15	SVN	SVN	15	15	USA	POL	15	15	USA	BEL	15	15	IRL
AUT	16	16	HUN	CAN	16	16	CAN	LVA	16	16	SGP	JPN	16	16	CZE
BEL	17	17	ESP	HUN	17	17	ISR	ESP	17	17	CAN	ESP	17	17	CAN
FRA	18	18	CZE	ISL	18	18	BEL	ISL	18	18	ESP	ISL	18	18	AUS
ISL	19	19	LVA	POL	19	19	ESP	ITA	19	19	ISR	PRT	19	19	ISR
ESP	20	20	KOR	KOR	20	20	ITA	CAN	20	20	ITA	HUN	20	20	SVN
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
GMB	121	121	CMR	NGA	121	121	MWI	ETH	121	121	CIV	UGA	121	121	MLI
SDN	122	122	TGO	CMR	122	122	UGA	LSO	122	122	MLI	ZMB	122	122	ZWE
CIV	123	123	ZMB	ZMB	123	123	AFG	YEM	123	123	SSA	SWZ	123	123	HTI
AFG	124	124	SWZ	ETH	124	124	CIV	COG	124	124	UGA	NGA	124	124	LSO
PNG	125	125	LSO	MWI	125	125	CMR	NGA	125	125	LSO	MLI	125	125	CMR
BEN	126	126	MWI	UGA	126	126	BEN	MWI	126	126	HTI	PNG	126	126	STP
CMR	127	127	UGA	TGO	127	127	MLI	UGA	127	127	CMR	SSA	127	127	SSA
OCE	128	128	ETH	HTI	128	128	PNG	HTI	128	128	OCE	MWI	128	128	OCE
LSO	129	129	SSA	AGO	129	129	OCE	TGO	129	129	PNG	MOZ	129	129	GIN
MLI	130	130	GIN	MRT	130	130	LSO	MLI	130	130	MWI	HTI	130	130	TGO
GIN	131	131	COG	MLI	131	131	SWZ	OCE	131	131	GIN	COG	131	131	SLE
LBR	132	132	MRT	COG	132	132	RWA	SSA	132	132	SLE	SLE	132	132	PNG
TGO	133	133	MLI	SSA	133	133	GIN	AGO	133	133	SWZ	YEM	133	133	LBR
RWA	134	134	AGO	MOZ	134	134	LBR	MOZ	134	134	LBR	OCE	134	134	SWZ
MOZ	135	135	BEN	GIN	135	135	MOZ	GIN	135	135	AGO	AFG	135	135	ZMB
SWZ	136	136	MOZ	BEN	136	136	TGO	SLE	136	136	TGO	GIN	136	136	MWI
ZMB	137	137	LBR	LBR	137	137	ZMB	BEN	137	137	ZMB	BEN	137	137	BEN
AGO	138	138	SLE	SDN	138	138	AGO	LBR	138	138	COG	AGO	138	138	COG
SLE	139	139	AFG	AFG	139	139	COG	AFG	139	139	BEN	LBR	139	139	MOZ
COG	140	140	SDN	SLE	140	140	SLE	SDN	140	140	MOZ	SDN	140	140	AGO

Table 11. Spearman's ranking coefficients of correlation

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,992**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,992**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
** Correlation is significant at the 0.01 level (2-tailed).				

CONCLUSION

The pursuit of growth and development have long been the primary objective for nations worldwide. However, it has become increasingly evident that development must be pursued in a sustainable manner because resources, particularly vital ones like fresh water, are depleting. This realisation has prompted nations to adopt measures that prioritize both the planet's well-being while pursuing their own economic development.

Sustainable Development Goals (SDGs), established by the United Nations, being among these measures is the focus of our study. Diverging from traditional approaches, our research does not assume that the goals are equally weighted. Instead, we employ Multi-Criteria Decision Making (MCDM) approach re-evaluate the rankings of the countries from a more objective standpoint in the SDG context.

By utilising Entropy- ARAS method, we determine different weights for each SDG. For instance, Goal 9 which pertains to Industry, Innovation and Infrastructure, carries the highest weight while Goal 14 focused on Life Below Water bears the lowest weight. Additionally, we observe a notable increase in the weight assigned to SDG 14 over the past two decades.

Furthermore, our study highlights that the utilisation of MCDM methods enhances the adaptability and precision of decision-making process when prioritizing targets for the inclusion of SDGs in a country's 2030 Agenda. This approach allows decision-makers to effectively weigh criteria and prioritize targets, even in the presence of uncertainty. The countries' ranks are modified after applying Entropy-ARAS method to determine the criteria weights to the rankings, which is a more objective method than simply taking the goal's simple average to determine the SDG index.This methodology enhances the accuracy and fairness of the rankins, accounting for the diverse importance of each goal and offering valuable insights into countries' progress toward sustainable development.

Countries should integrate the SDGs into their national development plans, policies and strategies while prioritizing specific goals based on their national context, needs and challenges.

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APPENDIX

A.I. Spearman's ranking coefficients of correlation for the first data set[7]

Table A.I. 1 Corelation between ARAS and TOPSIS method for the years between 2002 and 2006

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,995**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,995**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Table A.I. 2 Corelation between ARAS and TOPSIS method for the years between 2007 and 2011

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,995**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,995**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Table A.I. 3 Corelation between ARAS and TOPSIS method for the years between 2012 and2016

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,995**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,995**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Table A.I. 4 . Corelation between ARAS and TOPSIS method for the years between 2017 and 2021

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,995**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,995**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

7 SDG 1, SDG 4, SDG 9, SDG 10, SDG 13 are excluded in the first data set

Tables AI.1, AI.2, AI.3, AI.4 depict the correlation between the results obtained by ARAS and TOPSIS methods. They all present a high degree of correlation providing the robustness check for our findings.

A.II. Spearman's ranking coefficients of correlation for the second data set[8]

Table A.II. 1 Corelation between ARAS and TOPSIS method for the years between 2002 and 2006

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,992**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,992**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Table A.II. 2 Corelation between ARAS and TOPSIS method for the years between 2007 and 2011

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,994**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,994**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Table A.II. 3 Corelation between ARAS and TOPSIS method for the years between 2012 and 2016

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,994**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,994**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

8 Azerbaijan, Burundi, Burkina Faso, Brunei Darussalam, Botswana, Central African Republic, Congo Dem. Rep., Switzerland, Djibouti, Estonia, Kazakhstan, Luxembourg, Madagascar, Malaysia, Namibia, Niger, Qatar, Russian Federation, Somalia, South Sudan, Chad, Thailand, Uruguay, South Africa are excluded in the second data set.

Table A.II. 4 Corelation between ARAS and TOPSIS method for the years between 2017-2021

Correlations				
			ARAS	TOPSIS
Spearman's rho	ARAS	Correlation Coefficient	1,000	,992**
		Sig. (2-tailed)	.	,000
		N	163	163
	TOPSIS	Correlation Coefficient	,992**	1,000
		Sig. (2-tailed)	,000	.
		N	163	163
**. Correlation is significant at the 0.01 level (2-tailed).				

Tables AII.1, AII.2, AII.3, AII.4 demonstrate the correlation coefficients for the 5-years averages from 2002 to 2021. We find a strong correlation between the ranks produced by the ARAS and TOPSIS methods, with all correlation coefficients being significant at the 1% level.

A.III. Optimality function values (Si) and utility degree values Ki

Optimality function values (Si) and utility degree values Ki are calculated using Equation 14 and 15. Table A.III.1. demonstrate the values only for the 5 years average of 2002-2006 as an example.

Table A.III. 1 Optimality function values (Si) and utility degree values Ki.

Code	S_i	K_i	Ranking	Code	S_i	K_i	Ranking
SWE	0,017377	0,974812	1	DZA	0,005955	0,334029	71
NOR	0,015843	0,888731	2	BIH	0,005931	0,332692	72
JPN	0,015823	0,887607	3	PAN	0,005764	0,323321	73
FIN	0,015809	0,886848	4	KGZ	0,005659	0,317423	74
DNK	0,015412	0,864532	5	MDV	0,005644	0,31659	75
NLD	0,01525	0,855455	6	IRN	0,005573	0,312644	76
AUS	0,014966	0,839551	7	ALB	0,005551	0,311388	77
CAN	0,014919	0,836881	8	TKM	0,005499	0,308481	78
KOR	0,01483	0,831888	9	COL	0,005496	0,308307	79
DEU	0,014791	0,8297	10	LKA	0,005492	0,308053	80
GBR	0,014703	0,824773	11	UZB	0,005433	0,304764	81
SGP	0,014601	0,819041	12	SYR	0,005399	0,302847	82
ISR	0,014338	0,804318	13	PHL	0,005394	0,302562	83
USA	0,014284	0,801303	14	SLV	0,005358	0,300589	84
IRL	0,014183	0,795618	15	MNG	0,00534	0,29953	85
AUT	0,014162	0,794407	16	IRQ	0,005337	0,299361	86
BEL	0,01406	0,788694	17	DOM	0,00526	0,29505	87
FRA	0,013992	0,784889	18	PRY	0,005114	0,286885	88
ISL	0,013183	0,739534	19	TJK	0,005084	0,285169	89
ESP	0,012804	0,718253	20	IDN	0,005075	0,284668	90
ITA	0,012668	0,710604	21	IND	0,004949	0,277631	91
SVN	0,010839	0,608041	22	ETH	0,004896	0,27464	92
CZE	0,010547	0,591665	23	BOL	0,004868	0,273073	93
KWT	0,00964	0,540773	24	GAB	0,0048	0,269278	94
MLT	0,0096	0,538526	25	GUY	0,004703	0,26382	95
POL	0,009504	0,533112	26	NPL	0,004651	0,260884	96
PRT	0,009444	0,529778	27	NIC	0,004635	0,259996	97
HUN	0,009282	0,520665	28	BGD	0,00455	0,255214	98
CHN	0,0092	0,51609	29	GHA	0,00454	0,254652	99
SVK	0,00916	0,513831	30	SUR	0,004517	0,253371	100
HRV	0,009139	0,512687	31	BLZ	0,00448	0,251297	101
GRC	0,009087	0,509754	32	GTM	0,004428	0,248406	102
TUR	0,009038	0,506995	33	HND	0,004368	0,24501	103

CYP	0,008951	0,502133	34	BTN	0,004338	0,243366	104
BRA	0,008894	0,498907	35	STP	0,004282	0,240225	105
ARE	0,008403	0,471404	36	PAK	0,004274	0,239748	106
LTU	0,008168	0,458205	37	YEM	0,004229	0,237206	107
LVA	0,007982	0,447783	38	MMR	0,004185	0,234757	108
EGY	0,007697	0,431785	39	TZA	0,004169	0,23385	109
BLR	0,007659	0,429665	40	SEN	0,004114	0,230778	110
MNE	0,007542	0,423066	41	KEN	0,004001	0,224456	111
BGR	0,007478	0,419496	42	ZWE	0,003986	0,223589	112
BHR	0,007416	0,416025	43	HTI	0,003924	0,220138	113
CHL	0,007115	0,399101	44	LAO	0,003891	0,218276	114
SRB	0,007109	0,398777	45	MRT	0,003867	0,216921	115
CRI	0,007089	0,397688	46	NGA	0,003807	0,213556	116
UKR	0,007066	0,396358	47	KHM	0,003796	0,212946	117
JAM	0,006996	0,392427	48	MWI	0,003789	0,212531	118
VNM	0,006981	0,391585	49	UGA	0,003615	0,202774	119
TUN	0,006965	0,390737	50	GMB	0,003601	0,20198	120
BRB	0,00695	0,389886	51	SDN	0,003543	0,198726	121
LBN	0,006919	0,388145	52	CIV	0,003534	0,198229	122
SAU	0,006868	0,385245	53	AFG	0,003488	0,195657	123
PER	0,00686	0,384803	54	PNG	0,00348	0,195194	124
ARG	0,006844	0,383917	55	BEN	0,003473	0,194846	125
FJI	0,006789	0,380837	56	CMR	0,003438	0,192849	126
MKD	0,00665	0,373066	57	Oceania	0,003425	0,192137	127
JOR	0,006575	0,368828	58	LSO	0,003206	0,179845	128
ROU	0,006513	0,365348	59	MLI	0,00319	0,178958	129
CUB	0,006438	0,361137	60	GIN	0,003146	0,176462	130
MEX	0,006305	0,353662	61	LBR	0,003144	0,176343	131
OMN	0,006293	0,353033	62	TGO	0,003091	0,173412	132
MDA	0,006218	0,348813	63	RWA	0,003073	0,172375	133
VEN	0,006173	0,346278	64	MOZ	0,003033	0,170149	134
GEO	0,006147	0,344815	65	SWZ	0,002939	0,164887	135
MUS	0,006111	0,342795	66	ZMB	0,002868	0,160888	136
MAR	0,006095	0,341892	67	AGO	0,002673	0,14995	137
ECU	0,006085	0,341326	68	SLE	0,002631	0,147595	138
ARM	0,006057	0,339749	69	COG	0,002594	0,145514	139
TTO	0,006021	0,337779	70	Optimal	0,017827	1	

A.IV. Country Codes

Table A. IV. 1 Country Codes mostly based on International Standard ISO 3166-1, Codes for the representation of names of countries and their subdivisions--Part 1: Country codes, ISO 3166-1: 2006 (E/F), International Organization on Standardization (Geneva, 2006). Authors used different coding for Sub-Saharan Africa

AFG	Afghanistan	GHA	Ghana	NOR	Norway
ALB	Albania	GRC	Greece	Oceania	Oceania
DZA	Algeria	GTM	Guatemala	OMN	Oman
AGO	Angola	GIN	Guinea	PAK	Pakistan
ARG	Argentina	GUY	Guyana	PAN	Panama
ARM	Armenia	HTI	Haiti	PNG	Papua New Guinea
AUS	Australia	HND	Honduras	PRY	Paraguay
AUT	Austria	HUN	Hungary	PER	Peru
BHR	Bahrain	ISL	Iceland	PHL	Philippines
BGD	Bangladesh	IND	India	POL	Poland
BRB	Barbados	IDN	Indonesia	PRT	Portugal
BLR	Belarus	IRN	Iran, Islamic Rep.	ROU	Romania
BEL	Belgium	IRQ	Iraq	RWA	Rwanda
BLZ	Belize	IRL	Ireland	STP	Sao Tome and Principe
BEN	Benin	ISR	Israel	SAU	Saudi Arabia
BTN	Bhutan	ITA	Italy	SEN	Senegal
BOL	Bolivia	JAM	Jamaica	SRB	Serbia
BIH	Bosnia and Herzegovina	JPN	Japan	SLE	Sierra Leone
BRA	Brazil	JOR	Jordan	SGP	Singapore
BGR	Bulgaria	KEN	Kenya	SVK	Slovak Republic
KHM	Cambodia	KOR	Korea, Rep.	SVN	Slovenia
CMR	Cameroon	KWT	Kuwait	ESP	Spain
CAN	Canada	KGZ	Kyrgyz Republic	LKA	Sri Lanka
CHL	Chile	LAO	Lao PDR	Africa	Sub-Saharan Africa
CHN	China	LVA	Latvia	SDN	Sudan
COL	Colombia	LBN	Lebanon	SUR	Suriname
COG	Congo, Rep.	LSO	Lesotho	SWE	Sweden
CRI	Costa Rica	LBR	Liberia	SYR	Syrian Arab Republic
CIV	Cote d’Ivoire	LTU	Lithuania	TJK	Tajikistan
HRV	Croatia	MWI	Malawi	TZA	Tanzania
CUB	Cuba	MDV	Maldives	TGO	Togo
CYP	Cyprus	MLI	Mali	TTO	Trinidad and Tobago
CZE	Czech Republic	MLT	Malta	TUN	Tunisia
DNK	Denmark	MRT	Mauritania	TUR	Turkey
DOM	Dominican Republic	MUS	Mauritius	TKM	Turkmenistan
ECU	Ecuador	MEX	Mexico	UGA	Uganda
EGY	Egypt, Arab Rep.	MDA	Moldova	UKR	Ukraine
SLV	El Salvador	MNG	Mongolia	ARE	United Arab Emirates
SWZ	Eswatini	MNE	Montenegro	GBR	United Kingdom
ETH	Ethiopia	MAR	Morocco	USA	United States
FJI	Fiji	MOZ	Mozambique	UZB	Uzbekistan
FIN	Finland	MMR	Myanmar	VEN	Venezuela, RB
FRA	France	NPL	Nepal	VNM	Vietnam
GAB	Gabon	NLD	Netherlands	YEM	Yemen, Rep.
GMB	Gambia	NIC	Nicaragua	ZMB	Zambia
GEO	Georgia	NGA	Nigeria	ZWE	Zimbabwe
DEU	Germany	MKD	North Macedonia		

Coding in this study is based on International Standard ISO 3166-1 as seen on the table A.IV.1. However, for the purpose of fitting in the large tables into the pages we changed Sub-Saharan Africa code to SSA.