Edith Johana MEDINA-HERNÁNDEZ*, Evelyn BARCO-LLERENA and Kelly Johanna MARBELLO-YEPES*****

Food security in the world: Disparities and opportunities by country income levels

This article examines the performance of ten food security indicators across 91 countries in the world, categorised by their income levels, to identify differences and similarities. The variations and covariations observed in a multivariate way are outlined through Biplot plots that summarise the results of a Principal Component Analysis (PCA). The results show a direct link between the economic factors of the countries, food security, nutrition, and its derivatives. High-income countries are the best place for their populations to access a nutritious and quality food supply to meet the dietary energy needs needed for an active life. In contrast, low- and lower-middle-income countries still have critical indicators of the prevalence of severe or moderate food insecurity, malnutrition, and other related diseases, such as anaemia.

Keywords: food security; multivariate analysis; sustainable development; SDG 2.
JEL classifications: Q18, O13

* Department of Mathematics and Statistics, Faculty of Sciences, Universidad del Tolima, 7300062 Ibagué, Colombia. Corresponding author: ejmedinah@ut.edu.co
** Planning Office, Universidad de San Buenaventura, 130010 Cartagena, Colombia.
*** Faculty of Basic Sciences, Universidad Tecnológica de Bolívar, 131001 Cartagena, Colombia.
Received: 10 June 2023; Revised: 16 October 2023; Accepted: 18 October 2023.

Introduction

Food security has become a critical pillar for socio-economic development in all world nations. Within the framework of the Sustainable Development Goals (SDGs), it is a specific objective among the seventeen proposed SDGs because SDG 2 seeks to generate global public policy actions to curb the suffering of hunger and the factors that lead to food insecurity among the population. Itis commonly understood as signifying restricted, inadequate, or uncertain access to healthy and nutritious food that allows the population to meet the energy requirements for a healthy and productive life.

According to the 2022 edition of the report on the state of food security and nutrition at the global level (FAO, 2022), the world is going backwards in its efforts to end hunger, drifting away from meeting the goals of SDG 2 by 2030. This is an effect of the COVID-19 pandemic, which has influenced the deterioration of food security in both developed and developing countries due to fluctuations in food supply and demand, increased costs, and market closures (Zurayk, 2020).

The Sustainable Development Report 2022 (Sachs *et al*., 2022) throws this into sharp relief. As the map in Figure 1 shows, the promotion of food security globally currently faces significant challenges, with the situation being most

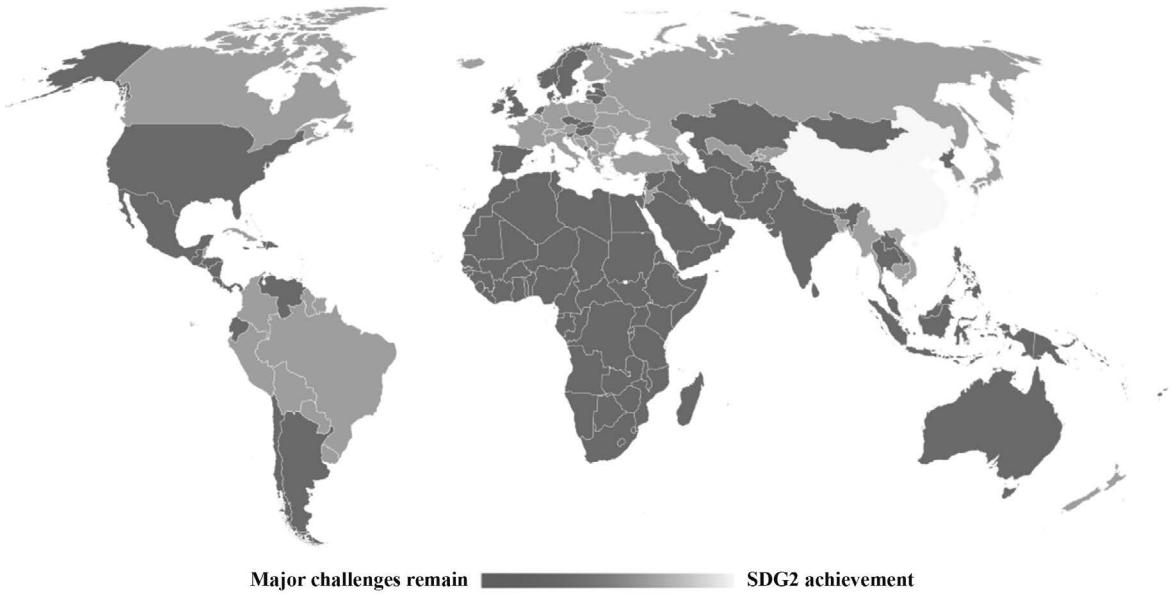

Figure 1: Current overview of the achievement of SDG2 in the world.
Source: Own composition based on data from Sustainable Development Report (2022)

acute among the nations of Africa, South, and West Asia, and even in developed countries such as Australia or the United States. States (regions plotted in orange). In these territories, the shortage of agricultural workers, the closure of food production due to the pandemic, and changes in consumer demand (Alabi and Ngwenyama, 2023), have together limited food supply chains in the post-COVID-19 era.

However, COVID-19 is not the only factor to have generated barriers to the production, access, and consumption of food by populations. As Awad (2023) observes, although food insecurity and malnutrition have been attributed mainly to conflicts, climate change, and economic crises in recent years, weak governments, low-income growth, and inadequate access to education for people represent additional barriers to addressing food security in an inclusive manner globally.

Consequently, it is necessary to acknowledge the factors that determine the prevalence of food insecurity in the world. At the macro level, this means the socio-political context of nations, their cultural characteristics, the prevalence of social structures and classes, public health policies, or even policies associated with food production that restrict the use of agricultural inputs that reduce output, farmers' incomes, and increase food prices (Baquedano *et al*., 2022). At the micro level, this means the socio-economic characteristics of the population and their housing economy, including gender and education of the household head, income, and poverty status of the households (Dasgupta and Robinson, 2022).

Concerning poverty specifically, several authors discuss how it connects with food insecurity (Zezza and Tasciotti, 2010; Mahadevan and Hoang, 2016; Seaman *et al*., 2014; Chegini *et al*., 2021) because it is a structural and multidimensional problem that encompasses various dimensions of deprivation related to human needs, such as food consumption, health, education, security, decent work, among others. Consequently, more policies based on the tenets of socio-economic inclusion need to guide the distribution of wealth and the promotion of economic participation to reduce inequality and improve food security and nutrition outcomes worldwide (Tamasiga *et al*., 2023).

In the recent academic literature, it is possible to reference authors who analyse the different factors that affect the population's food security, specifically through indicator analysis and modelling techniques. Valenzuela-Cobos *et al*. (2022) studied food sustainability in Ecuador using the PCA Biplot and GGE Biplot techniques to analyse flour samples of two cocoa mixtures, as this is the leading agricultural export product in the country. In their results, these researchers concluded that mixtures of cocoa husk flour with soybean meal can be used as ingredients to produce novel foods.

Kumar-Singh *et al*. (2022) evaluated food security indicators among the nations belonging to the South Asian Association for Regional Cooperation (SAARC), under changing climate scenarios and with a projection to 2050. This research concluded that food security indicators can be grouped according to four dimensions: availability of food, access to food, the use of its potential, and the stability of its production. Additionally, it was concluded that Bangladesh has the highest future projection of food security for its population in the region, followed by Sri Lanka. In contrast, the Maldives and Afghanistan were found to face critical scenarios based on the climate change scenarios evaluated.

Finally, Nouman *et al*. (2022) studied the impact of the green revolution on food security in Pakistan, using annual time series data from 1975-2017. By applying an autoregressive model, these authors concluded that agricultural machinery, agricultural credit, the use of fertilisers, high-quality seeds, fuel consumption, and the increase in the cultivated area of cereals; are the critical factors for a green revolution, which will improve food security in the country.

Taking all the above into consideration, this study analyses the current perspective of food security in the world by studying, from a multidimensional perspective, the behaviour of different indicators related to the framework of monitoring the progress of countries to meet the targets of SDG 2. To this end, three research questions are posed: Are statistically significant differences observed between food security indicators according to the countries' income levels? Which indicators generate the most remarkable differences? Which countries currently present the most critical challenges in seeking food security for their populations?

Materials and methods

Indicators and countries under analysis

Several international organisations regularly compile and publish information on food security indicators to promote sustainable development across nations, including those presented in Table 1. These are the indicators of interest in this study and are part of the FAOSTAT data repository of the Food and Agriculture Organization of the United Nations (FAO, 2023b), the Sustainable Development Goal indicators website (UN, 2023) and the World Bank Open Data portal (World Bank, 2023).

Indicators such as AGDP and AIGE are associated with agricultural indices measured in different nations around the world. In contrast, others correspond to estimates related to people's dietary and energy requirements (ADER, ADES, or DESU). The other indicators in Table 1 represent measures of the health and well-being of populations, specifically related to the prevalence of food insecurity and malnutrition.

The analysis of the behaviour of the food security indicators and their existing interrelationships is based on a study of the 91 countries included in the Table 2, which are grouped by the income levels defined by the World Bank. According to this classification, low-income economies have a gross domestic product (GDP) per capita of US$1,085 or less; in lower-middle-income countries, it ranges from US$1,086 to US$4,255; in upper-middle-income countries, the range is US$4,256 to US$13,205; and high-income nations have a GDP per capita of US$13,205 or more. Meanwhile, the 3-letter abbreviation of the countries' names has been used according to the ISO 3166 ALPHA-3 codification for the purposes of graphic representation.

Table 1: Food security indicators included in the analysis.

CODE	Variable	Source
ADER	Average dietary energy requirement (kcal/cap/day)	https://www.fao.org/faostat/en/#data/FS (indicator: 21057)
ADES	Average dietary energy supply adequacy (percent) (3-year average)	https://www.fao.org/faostat/en/#data/FS (indicator: 21010)
AGDP	Agriculture value added share of GDP (%)	https://unstats.un.org/sdgs/dataportal/database (indicator: AG_PRD_AGVAS)
AIGE	Agriculture orientation index for government expenditures	https://unstats.un.org/sdgs/dataportal/database (indicator: AG_PRD_ORTIND)
CVCC	Coefficient of variation of habitual caloric consumption distribution (real number)	https://www.fao.org/faostat/en/#data/FS (indicator: 21058)
DESU	The dietary energy supply used in the estimation of the prevalence of undernourishment (kcal/cap/day) (3-year average)	https://www.fao.org/faostat/en/#data/FS (indicator: 22000)
MSFI	Prevalence of moderate or severe food insecurity (%)	https://unstats.un.org/sdgs/dataportal/database (indicator: AG_PRD_FIESMS)
NSFP	Number of severely food insecure people (thousands of people)	https://unstats.un.org/sdgs/dataportal/database (indicator: AG_PRD_FIESSN)
PWAN	The proportion of women aged 15-49 years with anaemia (%)	https://unstats.un.org/sdgs/dataportal/database (indicator: SH_STA_ANEM)
UNSH	Prevalence of undernourishment (% of the population)	http://data.worldbank.org/indicator/SN.ITK.DEFC.ZS

Source: Own composition

Table 2: List and abbreviations of countries analysed.

Code	Country	Code	Country	Code	Country	Code	Country
Low-income economies							
BFA	Burkina Faso	ETH	Ethiopia	LBR	Liberia	MWI	Malawi
COD	Congo, Dem. Rep.	GMB	Gambia	MDG	Madagascar		
Lower-middle-income countries							
AGO	Angola	HND	Honduras	MRT	Mauritania	PHL	Philippines
BEN	Benin	IDN	Indonesia	MNG	Mongolia	SEN	Senegal
CPV	Cabo Verde	KEN	Kenya	MAR	Morocco	LKA	Sri Lanka
CIV	Cote d'Ivoire	KGZ	Kyrgyz Republic	MMR	Myanmar	TZA	Tanzania
EGY	Egypt	LAO	Lao	NPL	Nepal	UKR	Ukraine
SLV	El Salvador	LBN	Lebanon	NGA	Nigeria	VUT	Vanuatu
GHA	Ghana	LSO	Lesotho	PAK	Pakistan	VNM	Vietnam
Upper-middle-income countries							
ALB	Albania	CRI	Costa Rica	KAZ	Kazakhstan	PER	Peru
ARM	Armenia	ECU	Ecuador	MYS	Malaysia	SRB	Serbia
AZE	Azerbaijan	FJI	Fiji	MUS	Mauritius	ZAF	South Africa
BLZ	Belize	GEO	Georgia	MEX	Mexico	THA	Thailand
BWA	Botswana	GTM	Guatemala	NAM	Namibia		
BRA	Brazil	JAM	Jamaica	MKD	North Macedonia		
BGR	Bulgaria	JOR	Jordan	PRY	Paraguay		
High-income nations							
AUS	Australia	FIN	Finland	JPN	Japan	ROU	Romania
AUT	Austria	FRA	France	KOR	Korea, Rep.	SVK	Slovak Republic
BEL	Belgium	DEU	Germany	KWT	Kuwait	ESP	Spain
CAN	Canada	GRC	Greece	LTU	Lithuania	SWE	Sweden
CHL	Chile	HUN	Hungary	NLD	Netherlands	GBR	United Kingdom
CZE	Czech Republic	IRL	Ireland	NZL	New Zealand	USA	United States
DNK	Denmark	ISR	Israel	NOR	Norway	URY	Uruguay
EST	Estonia	ITA	Italy	PRT	Portugal		

Source: Own composition

Methodology

This study is a quantitative analysis that can be considered both descriptive and exploratory. It seeks to analyse the relationships between different food security indicators to identify both the most preponderant and those that determine the differences and similarities between countries. All the results were obtained using the statistical software R. Initially, a descriptive analysis was carried out to interpret the measures of central tendency of the food security indicators examined. Kruskal-Wallis and Dunn nonparametric hypothesis tests were afterwards applied to identify statistically relevant differences among income levels of the countries. Bivariate correlations between pairs of indicators were also calculated.

Finally, by using the Principal Component Analysis (PCA) technique, the behaviour of the bivariate and multidimensional associations observed was analysed by plotting the results of the reduction of the dimensionality of the data using Biplot graphs. According to Peña (2002), the main components have a double utility. First, they enable optimal representation of small numerical datasets. Second, they transform the original correlated variables into new uncorrelated variables, facilitating the interpretation of the data.

This technique aims to achieve the best representation of the attributes of the analysed information in the least number of dimensions possible. Graphically, through a Biplot, it is possible to summarise the information of variables (indicators represented by vectors) and individuals (countries, according to their 3-letter acronym) using the same reference system, providing the best Beta-barycentric representations and achieving the same quality of representation for the rows and columns of the data matrix (Galindo-Villardón *et al*., 1996).

Recently, analyses involving Biplot graphics have enjoyed a significant boom in scientific research, given their versatility in terms of the representation of results for the analysis of large-magnitude data. This is because they enable researchers to reference recent research in the field of agricultural sciences (Tatis-Diaz *et al*., 2022; Omrani *et al*., 2022; Silva *et al*., 2021), public health (Riera-Segura *et al*., 2022; Pozo *et al*., 2021), as well as studies with indicators in the field of sustainability (Medina-Hernández *et al*., 2023; Ruswandi *et al*., 2022; Valenzuela-Cobos *et al*., 2022; Martínez-Regalado *et al*., 2021).

Results

Descriptive analysis

Before presenting the results obtained through the multivariate analysis that allows the observed multidimensional associations to be summarised, it is pertinent to the discussion to show a descriptive exploration of the indicators under analysis and make comparisons among countries grouped by income levels. Table 3 summarises the basic statistics of each indicator. A marked tendency for all indicators to reflect differences in countries' income levels can be observed. For example, in the case of indicators associated with the dietary energy requirements of the population (ADER, ADES, and DESU), to the extent that the income level of the countries increases, the greater the median of these indicators is observed. On the contrary, the central tendency measures decrease as the income level of countries increases, among the indicators related to the prevalence of food insecurity or malnutrition such as MSFI, NSFP and UNSH.

To test the statistical significance of the differences observed in Table 3, and after examining that the indicators presented outliers, the data were evaluated as non-normal, and the Kruskal-Wallis test was performed, whose results are summarised in Table 4. For all the indicators examined, P values lower than a significance level $\alpha = 0.05$ were obtained. Therefore, with 95% confidence, it can be concluded that there are considerable differences between at least two of the income levels compared. Therefore, Table 4 also presents the results of the Dunn test, to test specifically between which levels the differences are recorded

Table 3: Basic statistics on indicators by country income levels.

Statistic	Income Level	ADER	ADES	AGDP	AIGE	CVCC	DESU	MSFI	NSFP	PWAN	UNSH
Median	1.Low	2,253.0	112.0	23.0	0.10	0.30	2,569.0	169.0	6,804.9	42.4	21.6
	2.Lower M.	2,313.0	120.5	13.3	0.15	0.28	2,847.0	90.1	2,490.4	32.9	5.7
	3.Upper M.	2,381.0	121.0	6.6	0.31	0.27	2,901.0	88.2	754.1	23.5	8.2
	4.High	2,483.0	135.0	1.9	0.40	0.21	3,365.0	23.6	417.9	13.2	2.5
	All Countries	2,391.0	123.0	6.0	0.25	0.26	2,922.0	60.7	1173.8	22.8	5.2
Mean	1.Low	2,262.9	111.1	30.0	0.12	0.31	2,516.7	180.2	13,126.5	40.0	20.8
	2.Lower M.	2,325.8	121.5	15.1	0.21	0.28	2,827.5	106.8	9,603.1	33.1	10.1
	3.Upper M.	2,375.4	119.4	7.0	0.46	0.28	2,837.8	87.3	3,538.6	23.6	11.5
	4.High	2,471.6	133.7	2.1	0.53	0.23	3,307.0	25.4	1,316.6	14.6	4.0
	All Countries	2,384.2	124.3	9.6	0.38	0.27	2,969.8	79.4	5,385.2	24.7	9.2
Standard deviation	1.Low	67.1	14.5	17.4	0.08	0.05	388.3	63.7	12,738.7	10.0	14.6
	2.Lower M.	98.8	12.7	7.7	0.15	0.06	345.4	60.0	15,176.3	12.6	10.3
	3.Upper M.	102.5	12.5	3.7	0.47	0.07	375.5	49.1	4,976.1	7.3	11.1
	4.High	88.4	11.3	1.4	0.46	0.04	321.9	14.1	3,643.6	4.5	3.4
	All Countries	116.2	14.1	10.3	0.40	0.06	429.2	64.1	10,382.1	12.3	10.2

Source: Authors' computations

Table 4 shows no statistically significant differences between the first two income levels in any indicators examined. This implies that although the World Bank considers nations that have a GDP per capita less than 1,085 US dollars as compared to those that increase to 4,255 dollars (respectively, income levels 1. Low and 2. Lower Middle) to be in different categories, in terms of food insecurity, the world's poorest nations have the highest prevalence of food insecurity. In complete contrast, the most industrialised countries and those with stable economies have the most favourable conditions. Note that the comparisons between levels 1. Low and 4. High (presented in the fifth column) are all significant.

To describe the bivariate correlations observed between pairs of indicators, Figure 2 presents a matrix of Spearman correlations (since non-normality was identified in the data),

Table 4: Kruskal-Wallis and Dunn test for differences by income level.

		dunn.test					
	kruskal.test	**1.Low**	**1.Low**	**1.Low**	**2.Lower M.**	**2.Lower M.**	**3.Upper M.**
		2.Lower M.	**3.Upper M.**	**4.High**	**4.Upper M.**	**4.High**	**4.High**
ADER	3.1x10-7 ****	0.242	0.069	7.3x10-5 ****	0.242	6.7x10-6 ****	0.007 **
ADES	4.4x10-5 ****	0.349	0.438	0.001 **	0.615	0.004 **	0.001 **
AGDP	1.9x10-14 ****	0.171	0.003 **	0 ****	0.006 **	0 ****	3.0x10-4 ***
AIGE	9.0x10-6 ****	0.504	0.011 *	0.001 ***	0.011 *	2.1x10-4 ***	0.504
CVCC	1.9x10-5 ****	0.646	0.646	0.001 **	0.918	0.001 ***	0.001 ***
DESU	4.9x10-7 ****	0.329	0.329	1.1x10-4 ***	0.859	6.6x10-5 ****	1.8x10-4 ***
MSFI	4.9x10-11 ****	0.153	0.074	4.0x10-7 ****	0.441	1.0x10-7 ****	6.6x10-6 ****
NSFP	3.2x10-5 ****	0.227	0.038 *	0.001 **	0.089	3.8x10-4 ***	0.197
PWAN	2.3x10-10 ****	0.246	0.035 *	3.8x10-6 ****	0.065	0 ****	0.001 ***
UNSH	1.76x10-6 ****	0.158	0.176	9.5x10-5 ****	0.746	0.001 ***	3.1x10-4 ***

Note: Significance levels are $\alpha = 0.1$ (∗), $\alpha = 0.05$ (∗∗), $\alpha = 0.01$ (∗∗∗) and $\alpha < 0.01$ (∗∗∗∗).
Source: Authors' computations

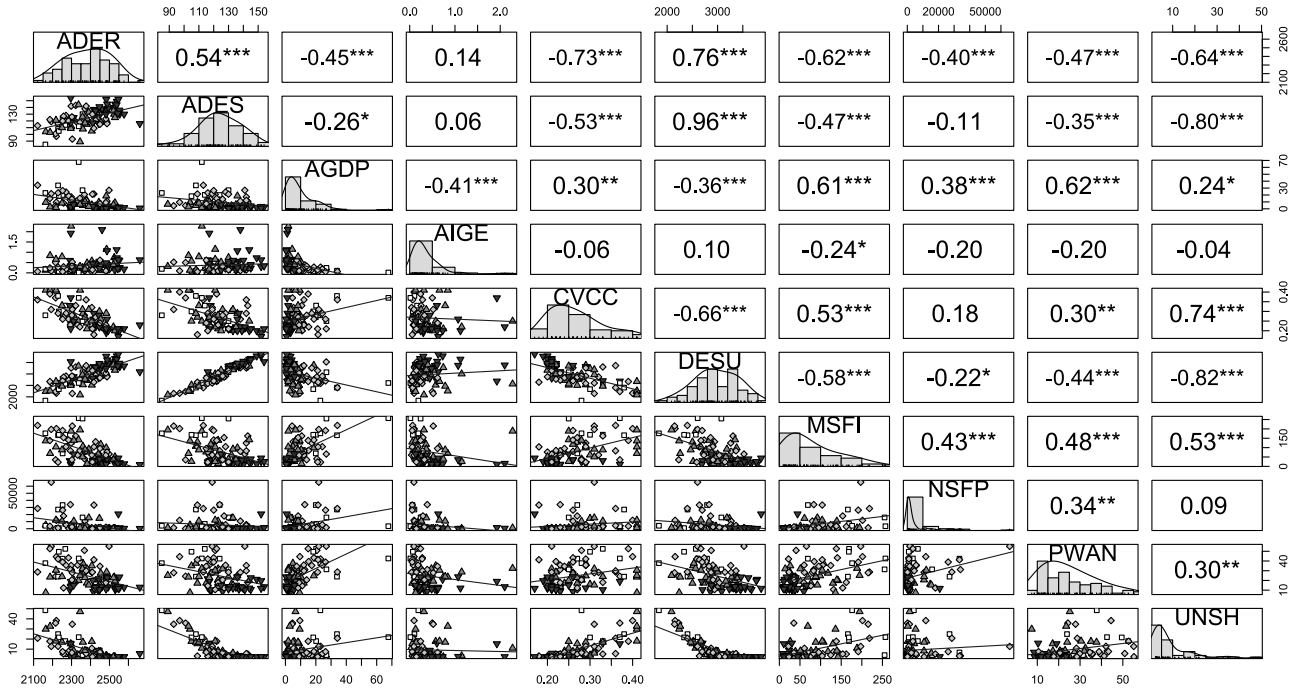

Figure 2: Bivariate correlation matrix between pairs of indicators.

Note: Significance levels are denoted as and
Source: Authors' elaboration in the statistical software R.

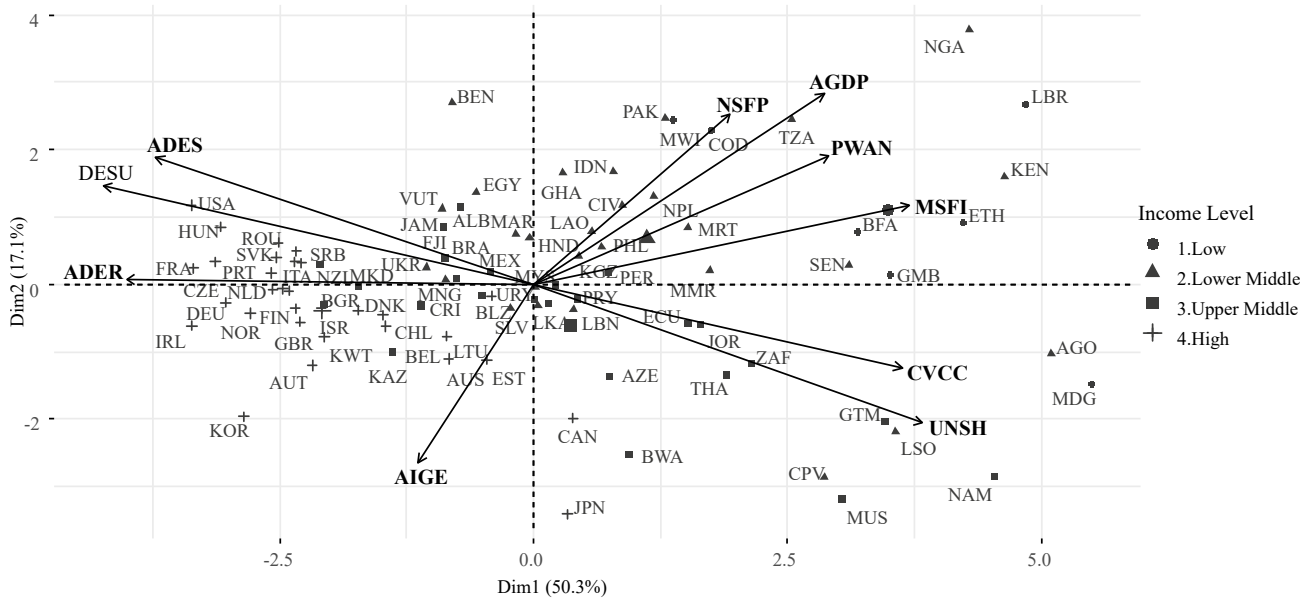

Figure 3: Food Security Indicators Biplot - PCA Analysis (Plain 1-2).
Source: Authors' elaboration in the statistical software R

differentiating countries' income levels with colours in the lower triangle. In the upper triangle of the matrix, the presented value corresponds to the calculated correlation for all countries and the stars denotes their statistical significance. It can be observed that different indicators show correlations with each other, reflecting an association by pairs.

Figure 2 shows a direct and strong covariation (with a value of 0.96) between the adequacy of the dietary energy supply (ADES) and the dietary energy supply used in estimating the prevalence of malnutrition (DESU) with a significance level of $\alpha<0.01$. In contrast, regarding the negative associations observed, there is also a negative correlation of -0.61 between the prevalence of moderate or severe food insecurity (MSFI), and the agriculture value added share of GDP (AGDP) index. This implies that in countries where agriculture accounts for a larger share of GDP, people are less likely to have the resources to obtain the food they need to live healthy, and well-being lives.

On the other hand, to give but one example of indicators among which no significant correlations are perceived, one can mention the observed association between ADES and CVCC, estimated at -0.06. This implies that an increase or decrease in one of these indicators provides no information about the behaviour of the other.

Multivariate analysis

To provide a multivariate summary of the variations and covariations observed between the indicators studied, Figure 3 presents the plane 1-2 of the Biplot that summarises the reduction of the dimensionality of the data. In this plane, 67.4% of information variability is shown (50.3% in the first dimension and 17.1% in the second). Therefore, when interpreting the associations observed at the level between vectors (which represent the relevant indicators) and the relative positions of countries (shown by colours according to income levels), 67.4% of all that could be said about the performance of food security indicators analysed.

The first pattern highlighted in Figure 3 is the countries' ordering from right to left according to income levels, which shows the relative advantage that high-income countries have in ensuring the food security of their populations. To the right of the graph and upwards (in the direction of the first quadrant of the plane) are the low- and lower-middle-income countries, in the direction of the vector cluster: MSFI, PWAN, NSFP, and AGDP, which positively covary with each other and are located in opposition to the AIGE vector.

These vectors represent, respectively, the prevalence indicators of moderate or severe food insecurity, the number of severely food insecure people, the proportion of women of reproductive age with anaemia, the value added of agriculture in GDP, and the agricultural orientation index for government expenditures. Observing the AIGE vector with an angle close to 180° relative to AGDP vector implies that although people in lower-income countries work in cultivating land for food production, Government expenditures to favour and promote productive initiatives in the agricultural sector tend to be low. This limits food production, access, and supply among populations, especially in rural areas.

To the left and up the plane of Figure 3 (in the direction of the second quadrant) are located the vectors ADES, DESU, and ADER, and those high- or upper-middle-income countries where the majority of inhabitants have access to sufficient food to meet their energy needs, and where governments promote food security and health policy. In contrast, down and to the right (in the direction of the fourth quadrant of the plane) are the countries with the highest rates of undernourishment. In six African countries, such percentages are greater than 30% of the population: Madagascar (MDG, 48.5%), Namibia (NAM, 47.2%), Angola (AGO, 38.3%), Cape Verde (CPV, 35.8%), Lesotho (LSO, 34.7%) and Mauritius (MUS, 32.7%).

Regarding the ranking of countries against axis 2, it should be noted that the heterogeneity observed between nations is generated by the AIGE vector, which is located closest to this axis and represents the estimate of the agricultural orientation index for government expenditures. Japan (JPN), Canada (CAN), Botswana (BWA), and the Republic of Korea (KOR) stand out for having the best values in the world in this index. It should also be noted that nations that are observed close to the midpoint of the plane (near the origin), as is the case of Latin American countries, tend to have "average values" for all the indicators analysed.

Discussion

In this study, differences statistically significant were observed among all the food security indicators examined when comparing the low and the high-income nations. Among lower-income countries prevalence of food insecurity and related (acute or chronic) diseases was observed that reflect low nutrient and food energy availability among vulnerable consumers (Unnevehr, 2015).

This outcome underscores the existing relationships between food security and sustainable development, socioeconomic factors, nutrition policy, governance, strategies to combat poverty, inequality, hunger, and food security management (Akbari *et al.,* 2022). Aspects that, after the occurrence of the COVID-19 health emergency, have revealed the vulnerability of global food systems to food safety risks, economic crises, and food price volatility (Panghal *et al.,* 2022).

Therefore, it is essential for developing nations to establish clear social policies that translate into tangible actions to reduce hunger and ensure the right to adequate and timely food. This is crucial to reduce health risks for the most vulnerable populations due to poor food safety (Gundersen and Ziliak, 2015). Additionally, policymakers in developing economies must prioritise job security to mitigate the adverse effects of income inequality on food security (Haini *et al.,* 2023).

In relation to the findings related to middle-income countries, particularly from the results of the multivariate analysis done, it was evident that they do not exhibit unfavourable conditions in all the studied indicators. These nations are actively working to implement public policy that favour investments on agricultural infrastructure, research, and development, and to transform their food systems governance (Lin *et al.,* 2022). However, they still face significant challenges in eradicating hunger and malnutrition in all its forms (FAO, 2023a). Furthermore, they also require seeking to lead the sustainable development from the fulfilment of the targets of SDG 2.

The analysed data indicate that such leadership currently primarily comes from developed nations. As Filippini *et al.* (2019) specify, high-income countries are implementing Urban Food Policies in three key areas: i) agriculture for food security; ii) governance and food economy; and iii) sustainable and healthy consumption. Regarding the first area, the results of this study related to the Agriculture Orientation Index for Government Expenditures (AIGE) showed that the agricultural sector plays a strategic role in improving food availability, both for developing countries (Pawlak and Kołodziejczak, 2020) and for the rural population of high-income countries (Kent *et al.,* 2022).

In summary, and as emphasised by FAO (2022), it is imperative for global agri-food systems to transform, become more resilient, and provide nutritious food at lower costs, ensuring affordable healthy diets for all in a sustainable and inclusive manner. Only by doing so can we aspire to achieve the SDG 2 targets in all nations, and not just the most developed ones.

Conclusions

This analysis highlights that the countries with better economic resources are those that best guarantee their populations that they can access the food that allows them to supply the caloric energies necessary to develop a whole and healthy life, free of malnutrition, and other related diseases, such as anaemia. In contrast, among lower-income countries, food insecurity is higher.

This result leads us to conclude that we must continue looking for strategies to address existing disparities between nations that generate systemic economic, political, and cultural inequalities, and re-politicise inequality (Collins, 2022), to favour a more equitable global food balance. Moreover, in the current geopolitical situation, global food security is threatened by the confluence of increasing demand for food due to a growing population and the inability of the food production system to meet the increasing demand due to climate change, worsening soil fertility, and the challenges to water availability (Rahut *et al*., 2022).

Public policy actions aimed at reducing the existing structural inequalities between countries according to their income levels, will also contribute to the fulfilment of SDG 2, given the connected nature of the objectives of the 2030 agenda. Addressing global sustainability challenges in this way endeavours to minimise poverty, inequality, and hunger globally as well as to deal with climate change and environmental degradation (Arora and Mishra, 2022).

Finally, it is worth noting this limitation of the study: it did not examine indicators associated with the components of food systems, such as consumer environments, the nature of food, access to food, or the nature of their retailing points (Moustier *et al.,* 2013). These aspects could provide a more detailed perspective on how countries should address the food security of their populations and so merit being addressed in future research aimed at providing targeted recommendations for specific groups of countries.

In addition, it is advisable for future studies to utilise multivariate analysis techniques to analyse SDG 2 indicators, trends and conditions that quantify the time required for the different economies of the world to achieve the Agenda 2030 goals. This is crucial because, as Pradhan (2023) observes, failing to meet SDGs will negatively affect the lives of billions of people and worsen socioeconomic and environmental crises, even though the COVID pandemic has decelerated or reversed the process of the Agenda.

References

Akbari, M., Foroudi, P., Shahmoradi, M., Padash, H., Parizi, Z.S., Khosravani, A., Ataei, P. and Cuomo, M.T. (2022): The evolution of food security: where are we now, where should we go next? Sustainability, **14** (6), 3634. https://doi.org/10.3390/su14063634.

Alabi, M.O. and Ngwenyama, O. (2023): Food security and disruptions of the global food supply chains during COVID-19: building smarter food supply chains for post COVID-19 era. British Food Journal, **125** (1), 167–185. https://doi.org/10.1108/BFJ-03-2021-0333.

Arora, N.K. and Mishra, I. (2022): Current scenario and future directions for sustainable development goal 2: a roadmap to zero hunger. Environmental Sustainability, **5**, 129–133. https://doi.org/10.1007/s42398-022-00235-8.

Awad, A. (2023): The determinants of food insecurity among developing countries: Are there any differences?, Scientific African, **19**, e01512. https://doi.org/10.1016/j.sciaf.2022.e01512.

Baquedano, F., Jelliffe, J., Beckman, J., Ivanic, M., Zereyesus, Y. and Johnson, M. (2022): Food security implications for low- and middle-income countries under agricultural input reduction: The case of the European Union's farm to fork and biodiversity strategies. Applied Economic Perspectives and Policy, **44** (4), 1942–1954. https://doi.org/10.1002/aepp.13236.

Chegini, K.R., Pakravan-Charvadeh, M.R., Rahimian, M. and Gholamrezaie, S. (2021): Is there a linkage between household welfare and income inequality, and food security to achieve sustainable development goals? Journal of Cleaner Production, **326**, 129390. https://doi.org/10.1016/j.jclepro.2021.129390.

Collins, A.M. (2022): Empowerment, rights, and global food governance: gender in the UN Committee for World Food Security. Globalizations, **19** (2), 220–237. https://doi.org/10.1080/14747731.2021.1877006.

Dasgupta, S. and Robinson, E.J.Z. (2022): Impact of COVID-19 on food insecurity using multiple waves of high frequency household surveys. Scientific Reports, **12**, 1865. https://doi.org/10.1038/s41598-022-05664-3.

FAO (2022): The State of Food Security and Nutrition in the World 2022. Rome (Italy).

FAO (2023a): Regional overview of food and nutrition security - Latin America and the Caribbean 2022: towards better affordability of healthy diets. Santiago (Chile).

FAO (2023): Food and agriculture data (FAOSTAT). Available at https://www.fao.org/faostat/en/#home (Accessed on 3 May 2023).

Filippini, R., Mazzocchi, C. and Corsi, S. (2019): The contribution of Urban Food Policies toward food security in developing and developed countries: A network analysis approach. Sustainable Cities and Society, **47**, 101506. https://doi.org/10.1016/j.scs.2019.101506.

Galindo, M.P., Barrera-Mellado, I., Fernández-Gómez, M.J. and Martín-Casado, A.M. (1996): Comparative study of ecological community management based on factorial techniques. Mediterránea. Serie de Estudios Biológicos, **15**, 55–61. https://doi.org/10.14198/mdtrra1996.15.06.

Gundersen, C. and Ziliak, J.P. (2015): Food Insecurity and Health Outcomes. Health Affairs, **34** (11), 1830–1839. https://doi.org/10.1377/hlthaff.2015.0645.

Haini, H., Musa, S.F.P.D., Wei Loon, P. and Basir, K.H. (2023): Does unemployment affect the relationship between income inequality and food security? International Journal of Sociology and Social Policy, **43** (1/2), 48–66. https://doi.org/10.1108/IJSSP-12-2021-0303.

Kent, K., Alston, L., Murray, S., Honeychurch, B. and Visentin, D. (2022): The Impact of the COVID-19 Pandemic on Rural Food Security in High Income Countries: A Systematic Literature Review. International Journal of Environmental Research and Public Health, **19** (6), 3235. https://doi.org/10.3390/ijerph19063235.

Kumar-Singh, R., Kumar-Joshi, P., Prasad-Sinha, V.S and Kumar, M. (2022): Indicator based assessment of food security in SAARC nations under the influence of climate change scenarios. Future Foods, **5**, 100122. https://doi.org/10.1016/j.fufo.2022.100122.

Lin, H.I., Yu, Y.Y., Wen, F.I. and Liu, P.T. (2022): Status of Food Security in East and Southeast Asia and Challenges of Climate Change. Climate, **10** (3), 40. https://doi.org/10.3390/cli10030040.

Mahadevan, R. and Hoang, V. (2016): Is There a Link Between Poverty and Food Security? Social Indicators Research, **128**, 179–199. https://doi.org/10.1007/s11205-015-1025-3.

Martínez-Regalado, J.A., Murillo-Avalos, C.L., Vicente-Galindo, P., Jiménez-Hernández, M. and Vicente-Villardón, J.L. (2021): Using HJ-Biplot and External Logistic Biplot as Machine Learning Methods for Corporate Social Responsibility Practices for Sustainable Development. Mathematics, **9**, 2572. https://doi.org/10.3390/math9202572.

Medina-Hernández, E.J., Guzmán-Aguilar, D.S., Muñiz-Olite, J.L. and Siado-Castañeda, L.R. (2023): The current status of the sustainable development goals in the world. Development Studies Research, **10** (1), 1–13. https://doi.org/10.1080/21665095.2022.2163677.

Moustier, P., Holdsworth, M., The Anh, D., Seck, P.A., Renting, H., Caron, P. and Bricas, N. (2023): The diverse and complementary components of urban food systems in the global South: Characterization and policy implications. Global Food Security, **36**, 100663, 1–11. https://doi.org/10.1016/j.gfs.2022.100663.

Nouman, M., Khan, D., Ul-Haq, I., Naz, N., Zahra, B.T.E. and Ullah, A. (2022): Assessing the implication of green revolution for food security in Pakistan: A multivariate cointegration decomposition analysis. Journal of Public Affairs, **22** (1), e2758. https://doi.org/10.1002/pa.2758.

Omrani, A., Omrani, S., Khodarahmi, M., Shojaei, S.H., Illés, Á., Bojtor, C., Mousavi, S.M.N. and Nagy, J. (2022): Evaluation of Grain Yield Stability in Some Selected Wheat Genotypes Using AMMI and GGE Biplot Methods. Agronomy, **12** (5), 1130. https://doi.org/10.3390/agronomy12051130.

Panghal, A., Mor, R.S., Kamble, S.S., Khan, S.A.R., Kumar, D. and Soni, G. (2022): Global food security post COVID-19: Dearth or dwell in the developing world? Agronomy Journal, **114**, 878–884. https://doi.org/10.1002/agj2.20932.

Pawlak, K. and Kołodziejczak, M. (2020): The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production. Sustainability, **12** (13), 5488. https://doi.org/10.3390/su12135488.

Peña, D. (2002): Multivariate data analysis. McGraw-Hill, Madrid, Spain.

Pozo, S., Carrillo, G. and Amaro, I.R. (2021): An Exploratory Analysis of COVID-19 in South America. In: Iano, Y., Saotome, O., Kemper, G., Mendes de Seixas, A.C. and Gomes de Oliveira, G. (eds). Proceedings of the 6th Brazilian Technology Symposium (BTSym'20). BTSym 2020. Smart Innovation, Systems and Technologies 233. Springer, Cham.

Pradhan, P. (2023): A threefold approach to rescue the 2030 Agenda from failing. National Science Review, **10** (7), 1–3. https://doi.org/10.1093/nsr/nwad015.

Rahut, D.B, Aryal, J.P., Manchanda, N. and Sonobe, T. (2022): Chapter 6 - Expectations for household food security in the coming decades: A global scenario. In: "Future Foods. Global Trends, Opportunities, and Sustainability Challenges". Academic Press, 107–131.

Riera-Segura, L., Tapia-Riera, G., Amaro, I.R., Infante, S. and Marin-Calispa, H. (2022): HJ-Biplot and Clustering to Analyze the COVID-19 Vaccination Process of American and European Countries. In: Narváez, F.R., Proaño, J., Morillo, P., Vallejo, D., González Montoya, D. and Díaz, G.M. (eds). Smart Technologies, Systems and Applications. SmartTech-IC 2021. Communications in Computer and Information Science 1532. Springer, Cham.

Ruswandi, D., Syafii, M., Wicaksana, N., Maulana, H., Ariyanti, M., Indriani, N.P., Suryadi, E., Supriatna, J. and Yuwariah, Y. (2022): Evaluation of high yielding maize hybrids based on combined. Stability Analysis, Sustainability Index, and GGE Biplot. BioMed Research International, 3963850. https://doi.org/10.1155/2022/3963850.

Sachs, J., Lafortune, G., Kroll, C., Fuller, G. and Woelm, F. (2022): From Crisis to Sustainable Development: The SDGs as Roadmap to 2030 and beyond. Sustainable Development Report 2022.

Seaman, J.A., Sawdon, G.E., Acidri, J. and Petty, C. (2014): The Household Economy Approach. Managing the impact of climate change on poverty and food security in developing countries. Climate Risk Management, **4–5**, 59–68. https://doi.org/10.1016/j.crm.2014.10.001.

Silva, K.E F., DoVale, J.C., Fritsche-Neto, R. and Marques, J.N. (2021): GGE biplot projection in adaptability and stability inference of soybean in an agricultural center Paraná, Brazil. Revista Ciência Agronômica, **52** (1), e20207131. https://doi.org/10.5935/1806-6690.20210009.

Tamasiga, P., Onyeaka, H., Akinsemolu, A. and Bakwena, M. (2023): The Inter-Relationship between Climate Change, Inequality, Poverty and Food Security in Africa: A Bibliometric Review and Content Analysis Approach. Sustainability, **15** (7), 5628. https://doi.org/10.3390/su15075628.

Tatis-Diaz, R, Pinto Osorio, D., Medina-Hernández, E., Moreno-Pallares, M., Canales, F.A., Corrales-Paternina, A. and Echeverría-González, A. (2022): Socioeconomic determinants that influence the agricultural practices of small farm families in northern Colombia, Journal of the Saudi Society of Agricultural Sciences, **21** (7), 440–451. https://doi.org/10.1016/j.jssas.2021.12.001.

UN (2023): UNSTAT: SDG Indicators Database. Available at: https://unstats.un.org/sdgs (Accessed on 14 April 2023).

Valenzuela-Cobos, J.D., Guevara-Viejó, F., Vicente-Galindo, P. and Galindo-Villardón, P. (2022): Food Sustainability Study in Ecuador: Using PCA Biplot and GGE Biplot. Sustainability, **14** (20), 13033. https://doi.org/10.3390/su142013033.

Unnevehr, L. (2015): Food safety in developing countries: Moving beyond exports, Global Food Security, **4**, 24–29. https://doi.org/10.1016/j.gfs.2014.12.001.

World Bank (2023): World Bank Open Data. Available at: https://data.worldbank.org (Accessed on 18 April 2023).

Zezza, A. and Tasciotti, L. (2010): Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. Food Policy, **35** (4), 265–273. https://doi.org/10.1016/j.foodpol.2010.04.007.

Zurayk, R. (2020): Pandemic and Food Security: A View from the Global South. Journal of Agriculture, Food Systems, and Community Development, **9** (3), 17–21. https://doi.org/10.5304/jafscd.2020.093.014.