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Multivariate Analysis of Food Security and Its Driving Factors

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Abstract

The main objective of the presented paper was the analysis of the current state of food security in the world, segmentation of 100 selected countries and determination of its main driving factors. The analysis used 27 indicators covering 5 basic areas: agricultural production, poverty, demography, economic development, and environmental indicators. The analysis was based on data from the FAO and World Bank for the most recent available period, which was year 2020. The data dimension was reduced with the application of factor analysis, and the main driving factors of food sufficiency were determined. The result was 6 factors: technological development, economic development, agricultural production, environmental factor, and physical quality of life and environment. To group similar countries in terms of selected indicators, a cluster analysis was performed, whereby countries were grouped by similarity into three clusters. The 1st cluster consisted of the most economically developed countries, where only 2.54% of the population suffers from malnutrition. The countries in this cluster were characterized by high levels of economic development, high caloric intake of the population, and high, life expectancy. On the other hand, they recorded negative development in demographic indicators such as fertility and birth rates. The 2nd cluster included the poorest areas of the African continent, which were most endangered by direct food insufficiency (23.74% of the population). In contrast to the first cluster, these countries were characterized by low levels of economic development, high prices, and low-calorie intakes of the population, as well as low life expectancy, while on the other hand, these countries had high fertility and birth rates. The third largest cluster consisted of countries with a medium threat of food insufficiency, where 6.37% of the population suffers from malnutrition. The countries in the third cluster excelled in terms of crop and livestock production volumes, but in contrast to this, they achieved lower levels of fat, protein, and calorie intake of population.

Keywords

Food security issues, driving factors of food security, multidimensional analysis.

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Introduction

Population pressure is significantly concentrated mainly in larger urbanized units, which offer their inhabitants quality education, the opportunity to find a job in the labour market, health care, and concentration of all-important institutions. Yet, because of their boom, large, developed cities must contend with poverty, lack of adequate jobs, and environmental problems. Under such pressure, farmers are forced to change their approach to the land stock in a way that will have as little impact on its erosion as possible. Excessive deforestation is caused by land destruction due to violent urbanism. It is also important to consider production capacity of the soil. Factors adversely affecting the reduction of this capacity are negatively correlated with population pressure. It is therefore important for agricultural production to be diversified to ensure sufficient safe and nutritious food for the future (Putri et al., 2019).

There is a significant correlation between food availability and the occurrence of armed conflicts. Thus, it is obvious that the likelihood of conflict will mainly concern those areas where people suffer from long-term food deprivations. These attacks will focus especially on areas with a good agricultural base (Koren and Baggozzi, 2016).

The pressure caused by military conflicts creates enormous uncertainty. In recent years, we can talk about an intensification of the conflict on the African continent. The most significant escalation is observed especially in the Central African Republic, the Democratic Republic of Congo, and the NW Mozambique (FSIN and Global Network Against Food Crises, 2022). We saw similar adverse developments in the countries of West Africa. This is particularly the case for the states of Mali, Burkina Faso, and Niger, which make up the Sahel region (Raleigh et al., 2021). One of the main causes of conflict in this area is political decisions and constant power struggles. Drought and, in some areas, long rainy seasons are also contributing negatively to the negative development of the situation (Seter et al., 2016).

The countries of East Africa, in particular Ethiopia, South Sudan, Somalia, Burundi, Uganda, Rwanda, and the relevant regions have forced their inhabitants to flee their homes because of ongoing military conflicts. Limited supplies of resources, shutdowns of production, and widespread market restrictions have prevented access to food and necessities of life for thousands of people (FSIN and Global Network Against Food Crises, 2022). Food security may be threatened because of the deepening crisis, especially in the countries of the Middle East and North Africa that are dependent on food imports. The war has greatly disturbed global food security, which has already been affected in the past by rising prices of raw materials. The severely limited export possibilities of cereals and fertilizers in the Black Sea ports resulted mainly in an increase in the prices of wheat and related goods (Hassen and Bilali, 2022).

In Europe and Asia, we have seen also several significant conflicts that have affected the food insufficiency of the population, especially in countries such as Afghanistan, Iraq, Palestine, Syria, and Yemen. The conflict, which has significantly affected the European Union and global food security is war in Ukraine (FSIN and Global Network Against Food Crises, 2022). It has brought various socio-economic problems which have international impact. Russia and Ukraine have a significant share of corn and wheat exports, the prices of which have increased substantially due to the military conflict and sanctions against Russia. High prices of inputs to production and the production process itself will push commodity prices even higher, especially for energy-intensive goods. Oil and gas outages from Russia have significantly threatened individual countries, and therefore the primary goal should be to reduce dependence on energy imports and increase self-sufficiency (Mayr, 2022).

Climate change is also factor with a significant impact on crop cultivation. In the future, it will change substantially the cultivation of agricultural commodities in some regions. It is therefore important that crop production systems adapt more quickly to expanded urbanization, and the high rate of population growth, to ensure food sufficiency in the affected regions (Kogo, 2020).

Several predictions for the upcoming decades warn that population growth and changing consumer preferences caused by scarcity of land resources and drinking water will seriously threaten world food allocations. To avert these predictions, several measures have been proposed to regulate future food supplies to all parts of the world. These measures concern:

- changes in the eating habits of individuals,
- reducing food waste (Kummu et al., 2017),
- productivity growth, reduction inefficiencies and management costs, and overall improvement of cross-sectoral cooperation within the food sector through information technology (Bilali and Allahyari, 2018),
- reducing phosphorus, nitrogen, and carbon dioxide production to sustainable levels (Willet et al., 2019),
- optimization of distribution channels of agricultural production (Davis et al., 2017).

Nowadays, new forms and approaches to farming and processing of agricultural production are coming to the front. It is assumed that the use of genetically modified crops will play a key role in ensuring sufficient, safe, and sustainable food in the future. Through genetic modification, farmers can transform plants in a way that improves their resistance to drought, various diseases, and pests or enriches their nutritional value, which is an essential part of sustainable production in the context of population expansion and food shortages (Vij and Tyagi, 2007).

The consequences of climate change will also affect access to safe water. With current population growth and changing dietary habits, is predicted increase of current water demand by 22% by 2090 because of changing climatic conditions (Mekonnen and Gerbens-Leenes, 2020).

It is necessary to accurately predict the development and changes in population size which helps to detect problems related to the deficiency of resources in the future, such as a shortage of drinking water, fuel, electricity, and food. We should also focus on the environmental burden on the planet associated with overpopulation (Mazzuco and Keilman, 2020). Currently, about 8 billion people live in the world.

The main objective of the presented paper is to find an optimal segmentation of countries on food security and nutritional status that are similar in a cluster but are different from observations in other clusters with the application of cluster analysis. The partial objective was to identify the main driving factors of food security. This was achieved with the application of factor analysis, which allowed us to reduce the dimension of the data and determine facts that were used as input variables in cluster analysis.

Cluster analysis was used previously in several food and nutrition studies. Most of them applied this kind of analysis at the micro-level to create a typology of households based on their food security characteristics as Mariovet et al. (2019). Smith et al. (2000) analysed a sample of developing countries in the period of the 1990s and found poverty as the main constraint for food security improvement. According to his results, many countries also faced problems with national food availability, and cluster analysis in this case was used primarily for poverty mapping.

According to Babu and Gajanan (2022), there are three reasons to use cluster analysis for the investigation of food security:

- Poverty maps are an important tool for targeting resources and interventions more effectively.
- Maps allow visual comparison and help to investigate spatial trends, clusters, or other patterns in the data.
- As one maps the geographic data, it allows one to show variability in data, especially geographic variation in poverty, which is related to different conditions in resources and living conditions.

Several research has analysed dietary patterns by application of cluster analysis based on the data coming from the food frequency questionnaires (see, for example, Wirfalt and Jeffery 1997, Greenwood et al. 2000, Millen et al. 2001). It is important to note that these studies have been undertaken mainly for developed countries such as the United States and European countries. The findings of these studies, in general, indicate the existence of distinct dietary patterns in the analysed population.

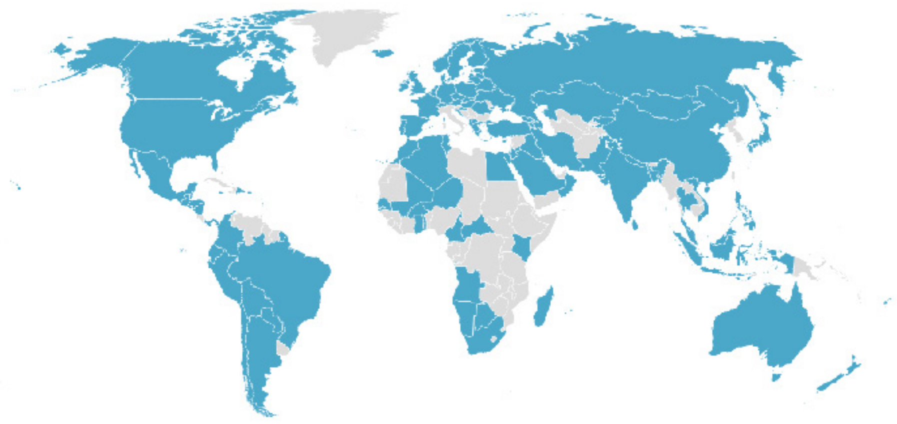
In addition, cluster analysis is usually applied to factor analysis when studying food security. Babu and Gajanan (2022) state two main advantages of this procedure:

- Factor analysis achieves data reduction and helps to summarize data when investigating food security. Analysed variables are usually linearly related to the Kaisere-Meyere-Olkin (KMO) measure which indicates that a factor analysis is appropriate method.
- Food security is determined by a set of complex variables, such as food accessibility, food availability, technology, economic development, and market access variables, it is important to condense the information contained in many variables into a smaller number of factors.

Materials and methods

Practical part of paper is devoted to the analysis of selected countries and their mutual characteristics. The choice of countries, analysed indicators, and the investigated period was influenced by the availability of data retrieved from the databases FAOstat and World Bank.

The following countries were included in the analysis: Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belize, Belgium, Bolivia, Botswana, Brazil, Burkina Faso, Canada, Cameroon, Chile, China, Central African Republic, Colombia, Croatia, Cyprus, Czech Republic, Dominican Republic, Denmark, Ecuador, Egypt, El Salvador, Estonia, Fiji, Finland, France, Germany, The Gambia, Georgia, Ghana, Greece, Guatemala, Honduras, Hungary, Iceland, India, Indonesia, Iraq, Iran, Ireland, Israel, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Latvia, Lithuania, Madagascar, Malaysia, Mali, Malta, Mauritius, Mexico, Mongolia, Morocco, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, North Macedonia, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Poland, Philippines, Portugal, Russia, Romania, Saudi Arabia, Senegal, Slovak Republic, South Africa, Sri Lanka, Spain, Switzerland, Sweden, Thailand, Togolese Republic, Tunisia, Turkey, Ukraine, England, United States and Vietnam. In total, analysis covers 110 world countries shown in Figure 1.



Source: Author´s work

Figure 1: Countries included in the presented study.

Countries were assessed based on 27 indicators in period of year 2020, which can generally be classified into the following 5 categories:

1. Agricultural output indicators

- Agricultural land per. capita (ha/km^2) – Agri_land,
- Agriculture, forestry, and fishing (in USD p. capita) - Forest,
- Cereal production per capita (in tonnes) – Cereal_p,
- Index of plant production (2014 – 2016 = 100) – Crop,
- Livestock production index (2014 – 2016 = 100) – Livestock,

2. Poverty indicators

- Access to clean fuels and cooking technologies (% of the population) – Tech_cook,
- Access to electricity (% of the population) – Electr,
- Fertility rate of adolescents aged 15-19 years (per 1000 women) – Adol_fert,
- Total population with access to safe drinking water (% of the population) – Water,
- Health care expenditure per capita (in USD) – Health_exp,
- Infant mortality (per 1000 live births) – Mort_rat,
- Prevalence of malnutrition (% of the population) – Undnrsh,
- Calorie intake per day (per capita) – Kcal,
- Protein intake per day (per capita) – Protein,
- Fat intake per day (per capita) – Fat,

3. Demographic indicators

- Birth rate, gross rate (per 1000 inhabitants) – Birth_r,
- Mortality, crude rate (per 1000 inhabitants) – Death_r,
- Total fertility (births per woman) – Fert_r,
- Life expectancy (years) – Life_exp,

4. Economic indicators

- Consumer price index (2010 = 100) – CPI,
- GDP per capita (2015 = 100, in USD) – GDP_pc,
- Household final consumption expenditure (% of GDP) – House_exp,

5. Environmental indicators

- Methane emissions from agricultural production (in tonnes p. capita) – Meth_em,
- Nitrous oxide emissions from agricultural production (in tones p. capita) – Nitro_em,
- Fertiliser consumption (kg per ha) – Fertiliz_con,
- Pesticide consumption in agriculture (in tonnes p. capita) – Pesticid_agr,
- Temperature changes (in ℃) – Temp.

The relationship between input variables was analysed using Pearson´s correlation coefficients, which can be calculated using the following Equation 1:

$$r_{xy} = \frac{cov(X,Y)}{s_X s_Y} \quad (1)$$

Where *cov(x,y)* is the covariance between *X* and *Y*,

s_X is the standard deviation of *X*,

s_Y is the standard deviation of *Y*.

A value close to 1 means a strong positive relationship – if the first variable increase, then increase also the second variable. Correlation coefficient values close to 0 mean weak or no relationship between variables. Value close to -1 means a strong negative relationship – if the first variable increase, the second one decrease. The significance of correlation coefficient can be verified using test statistics in the form of Equation 2:

$$t = r\sqrt{\frac{n-2}{1-r^2}} \quad (2)$$

Where *t* denotes test statistics value,

r value of correlation coefficient and

n number of observations

Statistics follow t distribution with *n*-2 degrees of freedom.

If the test statistics exceed the critical value, it means the rejection of the null hypothesis about the zero value of the correlation coefficient and the relationship between variables is significant. On the other side, if the test statistics are smaller than the critical value, the correlation between variables is not significant.

Factor analysis was applied to reduce the data dimension and to determine driving factors of food security.

In general, factor analysis can be described as a multidimensional statistical method whose main goal is to reduce data dimension from a wide range of variables and summarize it into smaller number of factors. It assumes multicollinearity in data, which is eliminated by its application. Furthermore, the Kaiser-Mayer-Olkin measure characteristic was used (Equation 3):

$$KMO = \frac{\sum_{i\neq j}^{m}\sum_{j\neq i}^{m} r_{ij}^2}{\sum_{i\neq j}^{m}\sum_{j\neq i}^{m} r_{ij}^2 + \sum_{i\neq j}^{m}\sum_{j\neq i}^{m} a_{ij}^2} \quad (3)$$

Where r_{ij}^2 – Pearson´s correlation coefficient between two variables

a_{ij}^2 - partial correlation coefficient

Countries were divided into clusters according to their level of food security indicators using cluster analysis. Driving factors of food security obtained by factor analysis were used as input to cluster analysis.

The main idea behind grouping objects into clusters is their similarity to each other. It is therefore desirable that objects included in the same cluster should be as similar as possible and, conversely, that they should differ as much as possible from objects classified in other clusters (Stankovičová and Vojtková,2007). In the presented paper was used Ward´s minimum variance method of clustering with Euclidean distance between points.

The selection of number of significant clusters is first step in this analysis. This can be determined from a heuristic point of view, where decisions are made based on an assessment of the graphical results of the dendrogram or by using aggregation quality indicators, which include standard deviation, coefficient of determination, semi-partial coefficient of determination and cluster distance. Analysis was performed in SAS Enterprise Guide 7.1.

Results and discussion

The analysis included 100 countries from around the world in the period of year 2020. Based on indicators of agricultural production, poverty, demography, economic development, and environmental indicators, it can be concluded, that on average 92.26% of the population of analysed countries has access to electricity (Electr), while there are countries where only about 15% of the population has access to electricity (Table 1). On average, 92.8% of the population has access to safe drinking water, but minimum value is only 49% of the population. The cereal production per capita in tonnes (Cereal_p) also varies across regions. There are countries where production per capita is 2.34 tonnes, but also countries where cereals are not grown at all. The incidence of malnutrition (Undnrsh) also shows large regional differences. Average value in the sample was 7.52% of the population, which suffers from malnutrition, yet there are countries with value up to 52.2%. Health care (Health_exp) spending in countries ranges from $19.85 to $10921.01 per capita. This is also reflected in the Life Expectancy (Life_exp) indicator, with smaller value than 55 years in developing countries, while in economically developed countries it is up to 84.62 years. Among economic indicators, the Consumer Price Index (CPI) is interesting, ranging from 98.82 in developed countries to 895.09 in less developed regions. Descriptive characteristics of analysed indicators shows significant differences between world regions.

	Mean	St Dev	Minimum	Maximum
Tech_cook	78.97	30.30	0.80	100.00
Electr	92.26	18.66	15.47	100.00
Adol_fert	39.23	36.37	2.41	177.46
Agri_land	0.02	0.04	0.00	0.34
Meth_em	0.0007	0.0009	0.0000	0.0054
Nitro_em	0.0005	0.0006	0.0000	0.0041
Forest	495.22	372.95	111.17	2711.55
Water	92.80	10.88	49.00	100.00
Birth_r	16.99	8.82	6.80	45.59
Cereal_p	0.42	0.49	0.00	2.34
CPI	162.11	113.86	98.82	895.09
Health_exp	1542.93	2256.10	19.85	10921.01
Death_r	8.47	2.95	2.91	15.90
Fert_r	2.29	1.15	1.13	6.89
Fertiliz_con	202.16	311.69	0.19	1952.09
GDP_pc	15779.33	19142.38	375.22	84434.78
House_exp	61.46	12.62	24.86	91.20
Life_exp	73.86	6.63	54.60	84.62
Mort_rat	14.60	14.88	1.50	77.50
Undnrsh	7.52	8.49	2.50	52.20
Kcal	2977.71	449.77	1846.70	3829.00
Protein	84.80	20.52	25.01	135.25
Fat	97.88	38.07	23.15	177.60
Pesticid_agr	0.0006	0.0008	0.0000	0.0053
Temp	1.71	0.72	0.08	3.69
Crop	108.45	20.76	55.87	205.88
Livestock	108.64	14.73	86.39	177.18

Source: Author´s work based on data from FAO and World Bank

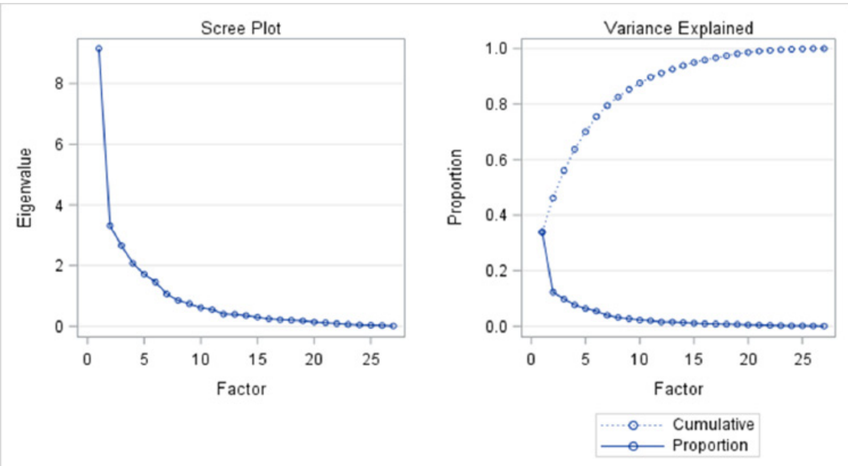
Table 1: Descriptive characteristics of analysed indicators.

To measure multicollinearity between indicators, was used the Pearson correlation coefficient, the results of which showed that there is a strong dependence between most indicators. KMO statistics reached 0.79, which means that data are suitable for factor analysis. The number of factors was determined according to eigenvalues and proportion of explained variability. The variability was explained at 79%, and the number of factors in which eigenvalues reached values greater than 1 was seven (Figure 2). The most of analysed variables are in first two factors, which explains approximately 50% of original indicators variability. In case of using just first two factors in further analysis, results would not consider agricultural production and environmental factors. This could cause smaller number of groups in results of cluster analysis.

Factor analysis was performed with orthogonal equamax rotation. Not all indicators had a clear classification, as the factor weights of some indicators exceeded value 0.5 within the two groups. Interpretation of these variables in relation to factors was based on logical reasons and a higher factor weight. The results and the actual classification of indicators into factors are presented in Table 2. The appropriate number of factors was 6 that can be seen in Table 2.

Based on results of factor analysis can be driving factors of food security interpreted as follows:

- Factor 1 – has the highest weights in variables electricity, access to water, life expectancy, and percentage of population with access to clean fuels and cooking technologies (Tech_cook variable), which



Source: Author´s work

Figure 2: Scree plot – determination of number of factors.

Rotated Factor Pattern						
	Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
Electr	**0.77**	0.13	0.25	-0.11	-0.36	-0.33
Water	**0.65**	0.24	0.42	-0.09	-0.32	-0.26
Life_exp	**0.64**	0.37	0.30	-0.11	-0.29	-0.42
Tech_cook	**0.62**	0.34	0.28	-0.05	-0.38	-0.21
Cereal_p	**0.52**	0.49	0.04	0.25	0.09	0.32
Undnrsh	**-0.63**	-0.36	-0.39	0.12	0.21	0.16
Adol_fert	**-0.63**	-0.16	-0.30	0.00	0.56	0.19
Mort_rat	**-0.68**	-0.26	-0.42	0.04	0.32	0.33
Birth_r	**-0.77**	-0.15	-0.37	-0.01	0.40	0.04
Fert_r	**-0.79**	-0.08	-0.36	-0.02	0.35	0.10
Health_exp	0.10	**0.83**	0.25	0.06	-0.26	-0.04
GDP_pc	0.12	**0.80**	0.26	0.12	-0.37	-0.11
Fat	0.40	**0.69**	0.39	0.09	-0.27	-0.04
Protein	0.50	**0.60**	0.32	0.09	-0.29	-0.04
Forest	0.07	**0.59**	0.20	0.26	-0.16	-0.33
Kcal	0.55	**0.59**	0.33	-0.06	-0.27	-0.09
CPI	-0.01	**0.58**	0.28	-0.12	-0.08	-0.12
Crop	-0.02	0.14	**0.86**	-0.14	-0.07	-0.20
Livestock	0.14	0.11	**0.75**	0.16	-0.17	0.40
Nitro_em	-0.05	0.13	0.03	**0.96**	-0.01	0.01
Meth_em	-0.04	0.12	0.01	**0.92**	0.05	-0.10
Agri_land	0.02	-0.16	-0.09	**0.82**	-0.07	0.08
House_exp	-0.07	-0.18	-0.15	-0.08	**0.63**	0.16
Pesticid_agr	0.33	0.30	0.27	0.10	**0.58**	-0.34
Death_r	-0.29	0.09	0.10	0.12	0.03	**0.81**
Temp	0.34	0.21	0.14	-0.18	-0.45	**0.60**
Fertiliz_con	-0.06	0.24	0.17	0.08	-0.27	**-0.56**

Source: Author´s work based on data from FAO and World Bank

Table 2: Factor weights after rotation.

can be concluded as development factor in technological sense.

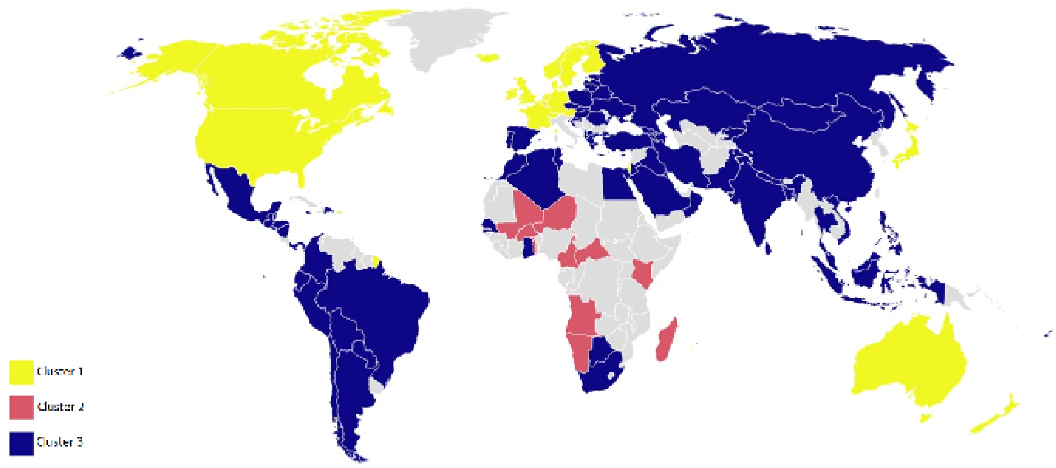
- Factor 2 – the highest weights have this factor for variables health expenditures, GDP per capita, and caloric, fat, and protein supply. This could be concluded as economic development because high values of these variables are characteristic for developed countries.
- Factor 3 – the highest weights have factor 3 for variables crop and livestock production, which could be concluded as a food production factor.
- Factor 4 – highest weights can be found in variables Nitro emissions, Methane emissions, and agricultural land. These variables could be concluded as environmental factors.
- Factor 5 – the highest weight has a factor in variables household expenditures and pesticides in agriculture.
- Factor 6 – highest weights have variables Death rate and temperature change. The last two factors are related to the physical quality of life and environment.

Subsequently, based on 6 factors described above was performed a cluster analysis The number of clusters was determined based on semi-partial coefficient of determination. The optimal number of clusters is 3 clusters. Based on the distribution function, which was used to verify the correct classification of countries in clusters with the cross-verification method, it could be considered to relocate Canada from cluster 1 to cluster 3 and Namibia from cluster 2 to cluster 3. Distribution of countries across clusters is shown on Figure 3.

The first cluster contained the most developed countries which are least affected by food insufficiency. Cluster included Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Japan, Malta, the Netherlands, New Zealand, Norway, Sweden, Switzerland, England, and the United States. 100% of the population in all these countries had access to the electricity. The same result was recorded also in case of the availability of green fuels and cooking technologies. In terms of the prevalence of malnutrition, all countries performed equally, with only 2.5% of the population. The average daily caloric consumption of an adult was 3051 kcal, with proteins making up 88 g and fat 106.5 g. 99.8% of the population had access to clean and safe water. The average gross domestic product was $49,523 per person. In terms of healthcare spending, the highest cost was about $10921 per person for residents of the United States, where life expectancy reached 77.3 years. Japanese residents lived the longest, dying on average at the age of 84.6 years. The largest area of agricultural land of 13.87 hectares per person was in Australia, where was recorded the highest use of pesticide with 2.5 kg per ha. of land. The largest grain producers included Canada, Denmark, and the United States of America, where the average grain production was 1540 kg per person. From a climatic point of view, this cluster experienced the highest temperature increase, with average value equal to 1.93 ℃.

The second cluster consisted of the poorest regions of the African continent, which were most at risk of direct food insufficiency. 11 countries were included in the cluster: Angola, Burkina Faso, Cameroon, Central African Republic, Gambia, Kenya, Madagascar, Mali, Namibia, Niger, and Togo. 52.2% of the Central African Republic population was at risk of malnutrition prevalence, followed by Madagascar with 48.5%. The average daily caloric consumption of an adult was 3031.34 kcal per day, while the daily intake of protein and fat was 86.7 g and 98.7 g, respectively. On average, 70% of the population had access to drinking water. Life expectancy does not vary significantly between countries in the second cluster, with an average value of 61 years. Demographically, there were an average of 35.8 births per 1,000 inhabitants. However, mortality in new-borns was high, with 46 dying out of 1,000 babies born. The highest recorded GDP per capita in second cluster was in Namibia equal about $4155.13. By contrast, the lowest GDP per capita in the Central African Republic was $375.22.

The third and most numerous cluster consisted of Albania, Algeria, Argentina, Armenia, Azerbaijan, Bangladesh, Belarus, Belize, Bolivia, Botswana, Brazil, Chile, China, Colombia, Croatia, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Fiji, Georgia, Ghana, Greece, Honduras, Hungary, India, Indonesia, Iraq, Iran, Jamaica, Jordan, Kyrgyzstan, Lithuania, Latvia, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Nepal, Nicaragua, North Macedonia, Oman, Pakistan, Panama, Paraguay, Peru, Poland, Philippines, Portugal, Russia, Romania, Saudi Arabia, Senegal, Slovak Republic, South Africa, Sri Lanka, Spain, Thailand, Tunisia, Turkey, Ukraine, and Vietnam. These countries could be



Source: Author´s work based on data from FAO and World Bank

Figure 3: Segmentation of countries into clusters.

characterized by medium risk of food insufficiency. The prevalence of food insufficiency was most obvious among the population of Botswana, where 21.9% of the population was directly at risk of food insufficiency. Daily caloric intake ranged from 1872 kcal to 3574 kcal per person, with Malaysian residents at the lower end of the range and Ghana residents at the upper limit. The average number of inhabitants with access to clean drinking water was 94.4%. Limited access to fuels and meal preparation technologies was most pronounced in Bangladesh, Fiji, Ghana, Guatemala, Honduras, Nepal, Pakistan, the Philippines, Sri Lanka, and Senegal, where the average population with access to these technologies was 38.6%. The country with the largest area of agricultural land was Mongolia, with a land area of 34.2 hectares per person. Lithuania became the largest grain producer per capita in 2020, accounting for 2340 kg of grain per person. Other important producers include Argentina with a production of 1910 kg of grain and Ukraine with 1460 kg of grain per capita. Life expectancy in third-cluster countries was 73.5 years. The lowest spending on health care was for Pakistani residents, with a share of $39.5 per person. By contrast, the highest $2711.19 value in cluster 3 was recorded in Spain.

It should be noted that year 2020 was influenced by spread of Covid 19 in the world. Variables such as health care expenditures, life expectancy and mortality rate could be influenced by pandemic situation, which should be considered when interpreting results. One of possible effect could be impact on reliability of collected data. The largest relative increase in mortality rate in pandemic year between analysed countries was recorded in Albania, Armenia, Chile, Ecuador, El Salvador, Japan, Mexico, Lithuania, and North Macedonia. Almost all countries belong to cluster 3, only Japan is from cluster 1. The largest decrease in life expectancy in pandemic year was recorded in Mexico, Bolivia, Azerbaijan, and Ecuador which are also countries from cluster 3. This result suggests, that Covid 19 pandemic has the worst impact on countries in cluster 3 and mostly on South American countries. Health care expenditures in 2020 in many countries increased, and the highest percentage increase due to pandemic situation was recorded in Armenia, Azerbaijan, Bangladesh, Ecuador, and China.

The overall comparison of clusters in terms of input indicators' mean values is shown in Table 3. The cluster with the highest value for every variable is highlighted in bold. The worst situation is in cluster 2. Countries in this cluster have the highest average fertility, and mortality rate with the smallest average life expectancy. There is also a slightly higher value of agricultural area, but on the other hand also the highest prices and expenditures in comparison with other clusters. Countries in this cluster have also the smallest agricultural production, problems with population access to water, and a significant prevalence of undernourishment in the population. An interesting fact is, that despite of significant prevalence of undernourishment in the population is average caloric supply in these countries higher than in cluster 3 countries.

Variable	Cluster 1	Cluster 2	Cluster 3
Tech_cook	**100**	15.08	83.05
Electr	**100**	44.87	97.57
Adol_fert	7.3	**108.55**	37.43
Agri_land	0.01	**0.02**	0.01
Meth_em	0	0.001	0.001
Nitro_em	0	0.001	0.001
Forest	**845.42**	224.58	436.86
Water	**99.85**	69.96	94.39
Birth_r	10.5	**35.8**	15.87
Cereal_p	**0.53**	0.16	0.43
CPI	114.72	**174.93**	173.8
Health_exp	**5562.09**	80.18	611.15
Death_r	**8.83**	8.4	8.38
Fert_r	1.6	**4.86**	2.08
Fertiliz_con	313.58	14.56	199.77
GDP_pc	49523.57	1235.84	8316.92
House_exp	49.94	**73.04**	62.95
Life_exp	**81.97**	61.08	73.55
Mort_rat	3.19	**46.18**	12.87
Undnrsh	2.54	**23.74**	6.37
Kcal	**3051.92**	3031.34	2947.65
Protein	**88.24**	86.72	83.5
Fat	**106.51**	98.68	95.25
Pesticid_agr	0	0.0001	0.001
Temp	**1.93**	1.27	1.71
Crop	93.74	111.78	**112.18**
Livestock	103.19	107.52	**110.39**

Source: Author´s work based on data from FAO and World Bank

Table 3: Comparison of mean values in clusters.

Cluster 1 is in sharp contrast with cluster 2. This cluster includes the most developed countries, with a high technological level of development. Countries have the highest agricultural production, the smallest average price index and household expenditures, and a very small prevalence of undernourishment. In contrast with cluster 2, it also has much higher life expectancy and smaller mortality rates, on the other side, with the lowest average birth and fertility rates.

It seems that cluster 3 is not interesting, because it does not look the best or the worst. But it is noteworthy, that this cluster recorded the highest average crop and livestock production compared to other clusters. Despite this fact was recorded the smallest average caloric, protein, and fat supply in this cluster.

Discussion

Results of presented paper divide countries into segments according to their food security performance. This helped to analyse spatial trends as it was stated by Babu and Gajanan (2022) and to analyse geographic variation in selected variables. Each segment should be treated differently to ensure sustainable food security. The worst situation is in countries in cluster 2. All countries within this cluster are from African region which is influenced by uncertainty caused by military conflicts, as it was stated by FSIN and Global Network Against Food Crises (2022) and Raleight et al. Results also confirmed conclusion by Seter et al. (2016) that negative development in this area is supported also by drought and water shortages. Significant problem could be possible also fast population growth which also confirmed Kogo (2020), Mazzuco and Keilman (2020).

On the other side, best food security level was recorded in cluster 1 which consists of the most developed countries. Food security issues in these countries have different nature. In these countries is enough food. Questionable can be its nutritional value. In contrast with prevalence of undernourishment in cluster 2 is large caloric intake per day in cluster 1. Results support suggestions by Kummu et al. (2017), that developed countries should focus more on changes in the eating habits of their inhabitants. These countries currently also use the highest number of fertilizers and are significantly influenced by climate change. Challenging for developed countries can be optimization of agricultural production in sustainable way and reducing emissions as it was suggested also by Willet et al. (2019) and Davis et al. (2017).

On the most numerous cluster 3 could be applied some characteristics from both previous clusters. This cluster does not seem to be interesting, because it is not the best nor the worst. To climate change and sustainability challenge could be added also fight with poverty in weak social groups, which remains the main constraint for food security improvement in many countries, especially in South American, African, and Asian countries within cluster 3. Social help could be addressed by created characteristics of food insecure households based on microdata similarly to study conducted by Mariovet et al. (2019) and Smith et al. (2000). Presented study created typology of countries, which could help to address appropriate food security help for analysed countries at global level.

Conclusion

Food security is a multidimensional issue related to many sociological, environmental, and economic aspects. The comparison of the examined countries was based on set of 27 indicators which covered 5 areas: agriculture, economy, poverty, demography, and environment. Results helped to identify similarities and differences among analysed countries. There has been significant contrast among the most advanced countries and food sufficiency of the least developed countries.

Variables in the selected 5 dimensions were used as the input to factor analysis to determine the main driving factors of food security. Based on its results were identified following factors: technological development, economic development, food production, environmental factor, and physical quality of life. These factors were used as inputs to cluster analysis to divide world countries into segments based on their food security situation. This procedure considered the multidimensional nature of the food security topic.

Based on the cluster analysis, countries were divided into three clusters, between which there are significant differences in most indicators. The first cluster consisted of economically developed countries with minimal levels of food insufficiency, the second cluster consisted of the least developed countries, and the third consisted of the largest group of countries with moderate levels of food security risk. Population of all countries in the first cluster have access to electricity. Third-cluster countries with moderate food insufficiency rates have access to electricity in an average of 97.6% of population. By contrast, only 44.9% of the population in the second cluster countries have access to electricity. In terms of growing cereals, which has a crucial role in food energy intake, China (3rd cluster) and the United States (1st cluster) were world leaders.

The results obtained in case of malnutrition incidence reflected significant differences between the studied countries. The conclusion was that countries in Africa, but also Central and South America and Asia, were most at risk. On average, people are malnourished in 23.74% of population of Cluster 2 countries, and in 6.37% of population in Cluster 2 countries. The relationship between malnutrition and the daily energy intake of adults has made it possible to analyse in-depth countries whose inhabitants should enrich their diets with energy-rich foods.

In case of limited resources of fresh drinking water, was analysis focused on countries where access to safe water was limited. It should be noted that the most vulnerable countries included Angola, Senegal, Namibia, Madagascar, Niger, Kenya, and the Central African Republic (1st cluster access to safe drinking water in 99.85% of population, second cluster 69.96% of population and third cluster 94.39%). Even though developed countries are not in risk in terms of drinking water access, it is assumed that by 2050 these countries will also record a water shortage. Another environmental problem which should be emphasized is the production of carbon dioxide, which, together with other greenhouse gases, has the largest influence on climate change. A major problem is also the dramatic deforestation that was recorded, both in the Amazon rainforest and in other parts of the world.

Comparison of clusters in terms of healthcare expenditure and related life expectancy also revealed significant differences. While Cluster 1 countries spend an average of $5562 per capita on health care and life expectancy is therefore the highest (81.97 years), in Cluster 2 countries health care expenditure is the lowest, averaging $80.18 per capita, which also affects the lowest life expectancy of 61.08 years.

The results of our analysis showed the contrast between the developed world and poor countries. Developed countries evaluated as food secure must solve issues with population aging and unhealthy diet. On the other side, African countries evaluated in our results as the most food insecure, have problems with the large prevalence of undernourishment, poor health care, and fast growth of population.

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