“Clustering countries of the world according to their business practices in agriculture”

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ARTICLE INFO	Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna and Oleksandr Tkachenko (2024). Clustering countries of the world according to their business practices in agriculture. *Problems and Perspectives in Management*, *22*(2), 352-364. doi:10.21511/ppm.22(2).2024.27
DOI	http://dx.doi.org/10.21511/ppm.22(2).2024.27
RELEASED ON	Monday, 20 May 2024
RECEIVED ON	Wednesday, 15 November 2023
ACCEPTED ON	Wednesday, 08 May 2024

JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
60	7	3

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

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CLUSTERING COUNTRIES OF THE WORLD ACCORDING TO THEIR BUSINESS PRACTICES IN AGRICULTURE

Received on: 15th of November, 2023
Accepted on: 8th of May, 2024
Published on: 20th of May, 2024

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Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

The study aims to cluster countries worldwide by business practices in the agrosector to reveal trends and specifics in applying sustainable methods in agrobusiness management. The analysis covers 26 countries from the OECD database as of 2021. The Word and k-means clustering methods are based on General Services Support Estimate indicators from the OECD: share of agricultural knowledge and innovation system, share of inspection and control, share of development and maintenance of infrastructure, share of cost of public stockholding, which has a determining, statistically significant influence on the formation of clusters. The first cluster included three Asian countries; China is the leader (share of agricultural knowledge and innovation system – 6,529.7 million USD, share of inspection and control – 3177.9 million USD, share of development and maintenance of infrastructure – 12,874.7 million USD, share of cost of public stockholding – 14,668.5 million USD). The second cluster comprised six countries, with the USA as the leader (share of agricultural knowledge and innovation system – 2,908.4 million USD, share of inspection and control – 1,298.0 million USD, share of development and maintenance of infrastructure – 2,392.5 million USD). The third cluster has 17 countries, with Canada being singled out (share of inspection and control – 631.8 million USD and share of agricultural knowledge and innovation system – 683.1 million USD). The results indicate the diversity of countries' approaches to support and develop their agrosector. Advanced Asian countries and the US invest significant resources in innovation, infrastructure development, and quality control, underscoring their commitment to food security, efficiency, and sustainability.

Keywords agriculture, hunger, food, insecurity, business, innovation, sustainability, state, OECD, GSSE

JEL Classification O13, Q01, Q18

INTRODUCTION

Today, the agricultural sector faces unprecedented challenges that require immediate and practical solutions. Geopolitical conflicts, economic shocks, global climatic extremes, and the aftermath of the COVID-19 pandemic are converging, creating a food crisis of unprecedented scale. According to the World Food Programme (WFP, 2024), in 2023, over 333 million people in 78 countries faced acute food shortages, nearly 200 million more than before the pandemic. Moreover, the crisis magnitude is underscored by the fact that in 2022, about 29.6% of people worldwide, or 2.4 billion, were living with moderate to severe food insecurity, of which nearly 900 million (representing 11.3% of the global population) endured severe food insecurity (FAO et al., 2023).

These events are evidence of deep structural problems in global agricultural production and distribution, threatening the achievement of the Sustainable Development Goals, especially SDG 2 Zero Hunger

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(the progress of which, according to the Sustainable Development Report 2023, is stagnating with major challenges), as well as the advancement of sustainable agricultural business practices (Sachs et al., 2023). In the face of constant climatic catastrophes, the agricultural sector must adapt to new production conditions, including developing and implementing innovative farming methods to reduce dependency on pesticides and fertilizers while ensuring resilience to climate change (Food Systems Countdown Initiative, 2023). The effective implementation of such business practices requires not only technological innovations but also a deep understanding of local ecosystems, the ability to anticipate changes, and the capacity to adapt to them with minimal losses.

While existing state support for the agricultural sector is substantial, several challenges must be overcome in implementing effective business practices. Investments in general agricultural services, such as research and development, biosecurity, infrastructure, and other clearly innovative and forward-looking expenditures that bring significant benefits to the sector, remain modest (OECD, 2023). Furthermore, at the state level, policies that support agricultural producers often need to be revised to facilitate climate change adaptation and promote sustainable development. One of the main issues is that a significant portion of such support is provided through price interventions and subsidies, which can distort markets and lead to inefficient resource use while limiting innovation and investments in environmentally sustainable technologies and business practices. Moreover, reforms in agricultural policy are often slowed down by the complexity of reconciling the interests of various stakeholders, including agricultural producers, consumers, and environmental organizations.

1. LITERATURE REVIEW

The issues of sustainable development and sustainable business practices have confidently occupied a central place in the scientific literature for more than two decades, considered fundamental to ensuring the long-term well-being of future generations (Yamaguchi et al., 2023; Singh & Pandey, 2023; Bhandari, 2023; Kuzior, 2010). In this context, Vasilyeva et al. (2022) modeled the balance of determinants of sustainable growth based on the definition of the center of mass. Their study became a pivotal contribution to understanding the dynamics between social, economic, and political spheres, digital capabilities, and the cybersecurity of countries.

According to Mursalov et al. (2023) and Melnyk et al. (2019), digitalization provides opportunities for developing and implementing sustainable business models that reduce costs, increase productivity, and ensure sustainable development. Andrișan and Modreanu (2022), Kolosok et al. (2022), and Kuzior and Lobanova (2020) emphasize that the integration of digital technologies, such as big data, IT innovations, artificial intelligence, and the Internet of Things (IoT), into business processes promotes the economic growth of enterprises. Moreover, it aids in achieving environmental and social goals, laying the foundation for the sustainable development of national economies and the global community.

The adaptation of business models to circular and additive economies, as noted by Melnyk et al. (2023), Kuzior et al. (2022), and Polyakov et al. (2021), becomes the basis for creating economically efficient and environmentally sustainable manufacturing processes. This approach not only facilitates the optimization of resource use and waste reduction but also opens new opportunities for enterprises to adapt to changing market conditions and challenges related to economic growth and regional disparities (Shvindina et al., 2019), various models of tax competition (Bilan et al., 2018), and stages of financial, business, and trust cycles (Bilan et al., 2019).

The contemporary business context emphasizes the necessity of integrating sustainable practices into strategic planning and measuring the success of companies. This is done not only based on financial outcomes but also considering social responsibility, environmental sustainability, and overall contributions to society (El Fallahi et al., 2023; Koibichuk et al., 2022; Dotsenko et al., 2023; Lahouirich et al., 2022; Babenko et al., 2022; Kuzior et al., 2021). Brychko et al. (2023) established that although the direct impact of sustainable development on enterprise development can be a subject of debate, a clear pattern between changes in the internal and external business environment initiated by sustainable development is confirmed. Kaya (2023), Zhghenti (2023), and Starchenko et al. (2021) emphasize the importance of adapting business models to changes in environmental conditions and other factors.

In agricultural sector, the importance of implementing sustainable business practices is underscored by the need for integrating innovative approaches to resource management, reducing negative impacts on ecosystems, and developing financial support mechanisms to ensure agricultural sustainability (Mullens & Shen, 2023; Richardson, 2023; Rakotoarisoa & Mapp, 2023; Bouchafaa et al., 2023; Berezhnytska et al., 2022; Davydenko et al., 2022; Singh, 2022; Vasylieva & James, 2020; Kolesnik et al., 2019; Melnyk & Kubatko, 2012). The significance of sustainable practices is also highlighted in research dedicated to the financial efficiency of agricultural companies (Lehenchuk et al., 2023), their innovative strategies (Miao & Kharchenko, 2023; Darchia, 2022), agricultural insurance (Juhászová et al., 2023), logistical challenges affecting the agricultural sector (Lyshenko et al., 2023), technology transfer and crisis management (Khalatur et al., 2023; Hakobyan et al., 2022).

Some studies demonstrate that integrating sustainable development principles can significantly improve not just the environmental indicators of agricultural enterprises but also their economic efficiency and social responsibility (Hadouga, 2023; Olaniyan & Adepeju, 2023; Vasylieva, 2020; Plastun et al., 2021). Moreover, organic farming and other eco-friendly land management methods help preserve biodiversity, improve soil and water quality, and ensure healthy food products for consumers (Dobrovolska & Espejo, 2018).

Despite numerous studies highlighting the importance of integrating sustainable business practices in the agricultural sector, there is a need for a deeper analysis of how different countries worldwide adapt and apply these practices in their agricultural models. Such analysis would help identify best practices, reveal gaps in knowledge and strategies, and facilitate the exchange of experiences between countries.

The goal of this study is to cluster countries worldwide by business practices in the agricultural sector, which will reveal general trends and specifics in the application of sustainable methods in agricultural business management.

2. METHODS

This study used open official statistical information on key indicators of the General Services Support Estimate (GSSE) from the international OECD database available for 26 countries of the world as of 2021. The GSSE represents the volume of gross cash transfers aimed at general services provided to agricultural producers and arising from policy measures that support agriculture (Table 1).

Clustering is done for objects with quantitative (numerical), qualitative, or mixed characteristics. The task of clustering is to divide objects into several subsets (clusters) in which objects are more similar than objects from other clusters. In metric space, "similarity" is usually defined as distance. The distance can be calculated both between the original objects (rows of the X matrix) and from these objects to the cluster prototype. Usually, the coordinates of the prototypes are not known in advance – they are found simultaneously by dividing the data into clusters.

Table 1. Input data

Indicator Code	Indicator Name	Measurement Unit
GSSE	General Services Support Estimate	Millions, USD
GSSE1	Share of agricultural knowledge and innovation system	
GSSE2	Share of inspection and control	
GSSE3	Share of development and maintenance of infrastructure	
GSSE4	Share of marketing and promotion	
GSSE5	Share of cost of public stockholding	
GSSE6	Share of miscellaneous	

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Clustering methods are divided depending on whether the number of clusters is determined in advance. In the latter case, the number of clusters is determined via the algorithm based on the initial data distribution.

Cluster analysis methods can be divided into two groups.

1. Hierarchical methods (the essence is the sequential merging of smaller clusters into larger ones or the division of larger clusters into smaller ones).

1.1. Hierarchical agglomerative methods (Agglomerative Nesting, AGNES). A consistent combination of initial elements and a corresponding reduction in the number of clusters characterizes this group of methods. The most similar objects are combined into a cluster in the first stage. In the following steps, the merging continues until all objects form a single cluster. The disadvantage of this algorithm is the one-factor nature of merging clusters with the impossibility of accounting for a group of similar indicators.

1.2. Hierarchical divisive (distributed) methods (Divisive Analysis, DIANA). This group of methods is the logical opposite of agglomerative methods. Initially, all objects belong to one cluster, which is divided into smaller clusters in the following steps, resulting in a sequence of splitting groups.

2. Non-hierarchical (the point is that in the process of distribution, new clusters are formed until the stopping rule is fulfilled).

2.1. The k-means algorithm. The general idea of the algorithm is that a given fixed number of k clusters of observations are mapped to clusters. Hence, the averages in the cluster (for all variables) differ as much as possible.

2.2. Algorithm PAM (Partitioning Around Medoids). PAM is a modification of the k-means, k-median algorithm (k-medoids). The algorithm is less sensitive to noise and data outliers than the k-means algorithm because the median is less affected by outliers and is effective for small amounts of data.

Thus, it is necessary to apply methods appropriate for a large amount of qualitative and quantitative data using vagueness and without prior cluster setting. This study uses a combination of two clustering methods: the hierarchical Word method for preliminary determination of the required number of clusters and the non-hierarchical k-means method, which allows for a detailed analysis of the principle of cluster formation and the contribution of indicators to their structure. All calculation steps were carried out using the mathematical software STATISTICA 12.

3. RESULTS

In the first stage of clustering using the hierarchical Ward method, it is necessary to determine the optimal number of clusters. For this purpose, a dendrogram must be constructed (Figure 1).

Based on the results of country redistribution using Ward's method, three clusters can preliminarily be identified:

- Cluster I includes four countries: China, India, the USA, and Japan;
- Cluster II includes five countries: Indonesia, Vietnam, the Philippines, Türkiye, and South Korea;
- Cluster III includes eighteen countries: the United Kingdom, New Zealand, Switzerland, Mexico, Colombia, Ukraine, Argentina, Norway, Kazakhstan, the Republic of South Africa, Israel, Iceland, Costa Rica, Chile, Brazil, Canada, and Australia.

Using the k-means clustering method, a graph of the average values of indicators GSSE1- GSSE6 within the identified clusters was obtained (Figure 2). Before proceeding to the qualitative assessment of the obtained average values of the indicators that underlie the identified clusters, it is necessary to additionally conduct an analysis of variance (Table 2).

Based on the analysis of variance, particularly on the *p*-value (which should be less than 0.05), four out of six indicators – the share of agricultural

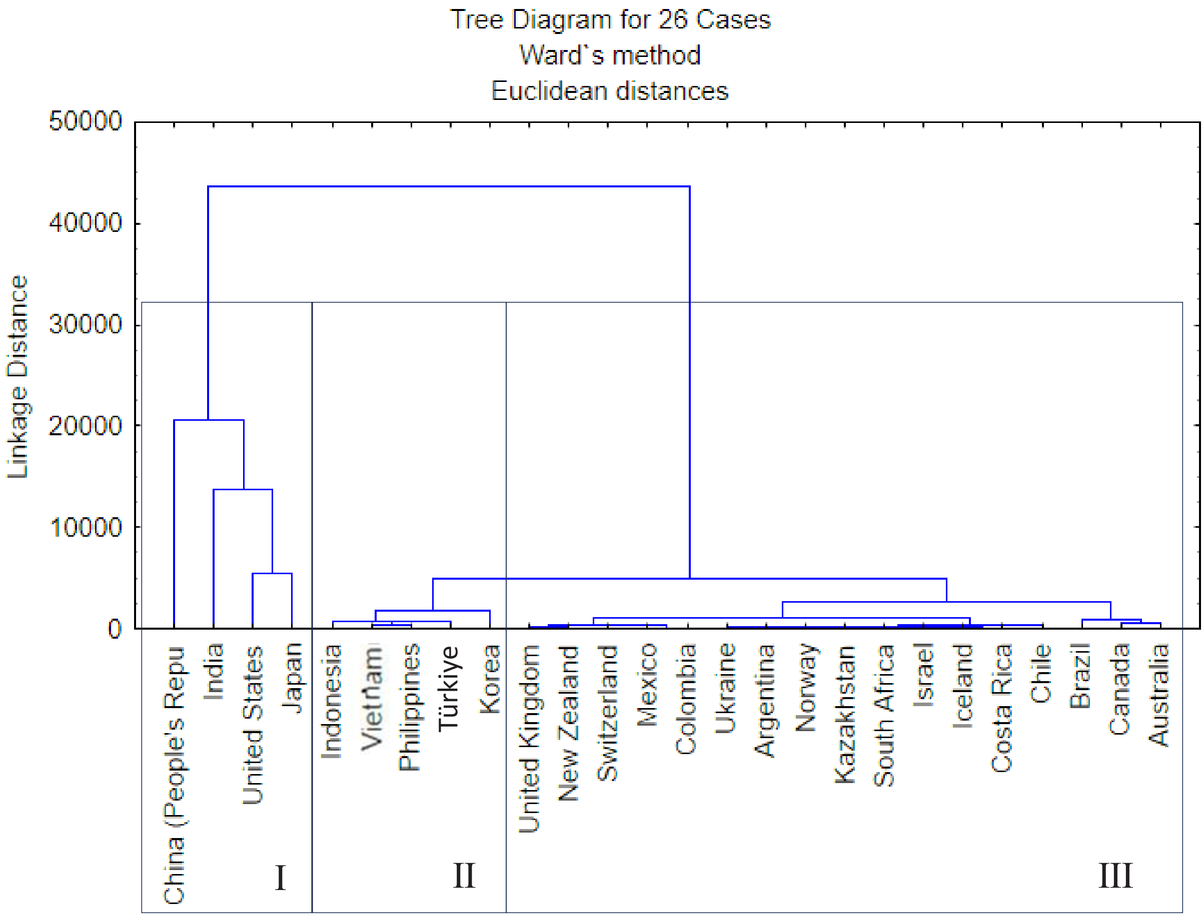

Figure 1. Dendrogram of redistribution of countries between clusters according to Ward's method

knowledge and innovation system, the share of inspection and control, the share of development and maintenance of infrastructure, and the share of cost of public stockholding – have a statistically significant impact on cluster formation. By removing the two insignificant indicators, reconstructing the dendrogram and the graph of averages, and conducting a new analysis of variance, the following results are obtained – Figures 3-4 and Table 3.

Table 2. Variance analysis

Indicator	Between SS	df	Within SS	df	F	p-value
GSSE1	35822020.0	2.0	9298481.0	23.0	46.2	0.000
GSSE2	8693420.0	2.0	1894546.0	23.0	55.1	0.000
GSSE3	354973500.0	2.0	48032370.0	23.0	88.7	0.000
GSSE4	193941.2	2.0	4929842.0	23.0	0.5	0.629
GSSE5	205401500.0	2.0	477246.4	23.0	5164.7	0.000
GSSE6	12316.3	2.0	2624152.0	23.0	0.1	0.945

Note: Between SS is the between-group variance, df stands for degrees of freedom, Within SS is the within-group variance, *F* represents the Fisher's F-statistic, and *p*-value is the probability of statistical significance.

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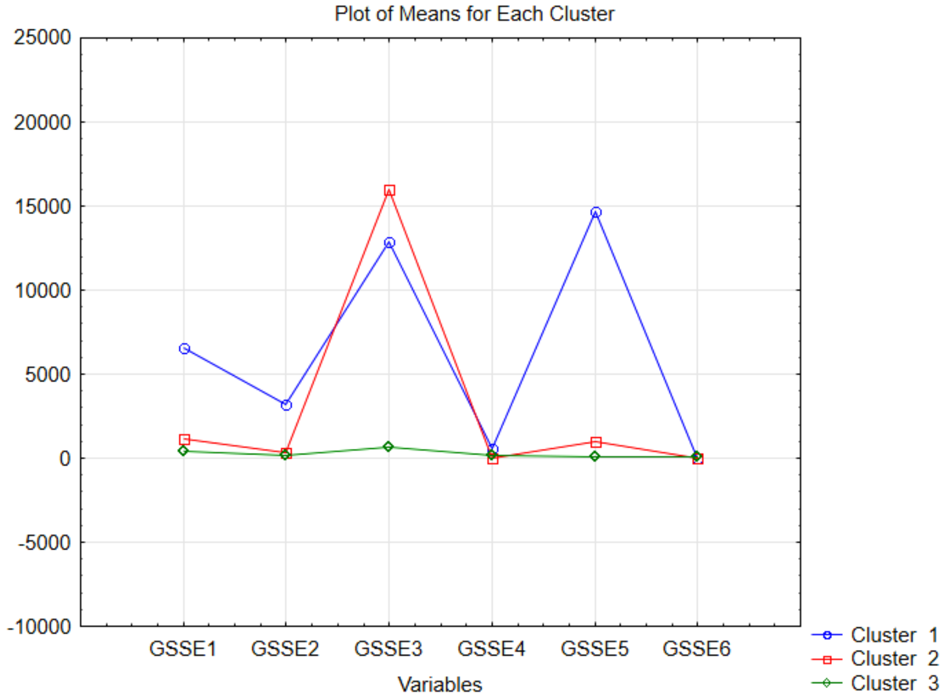

Figure 2. Average values of indicators GSSE1-GSSE6 within selected clusters by k-means clustering method

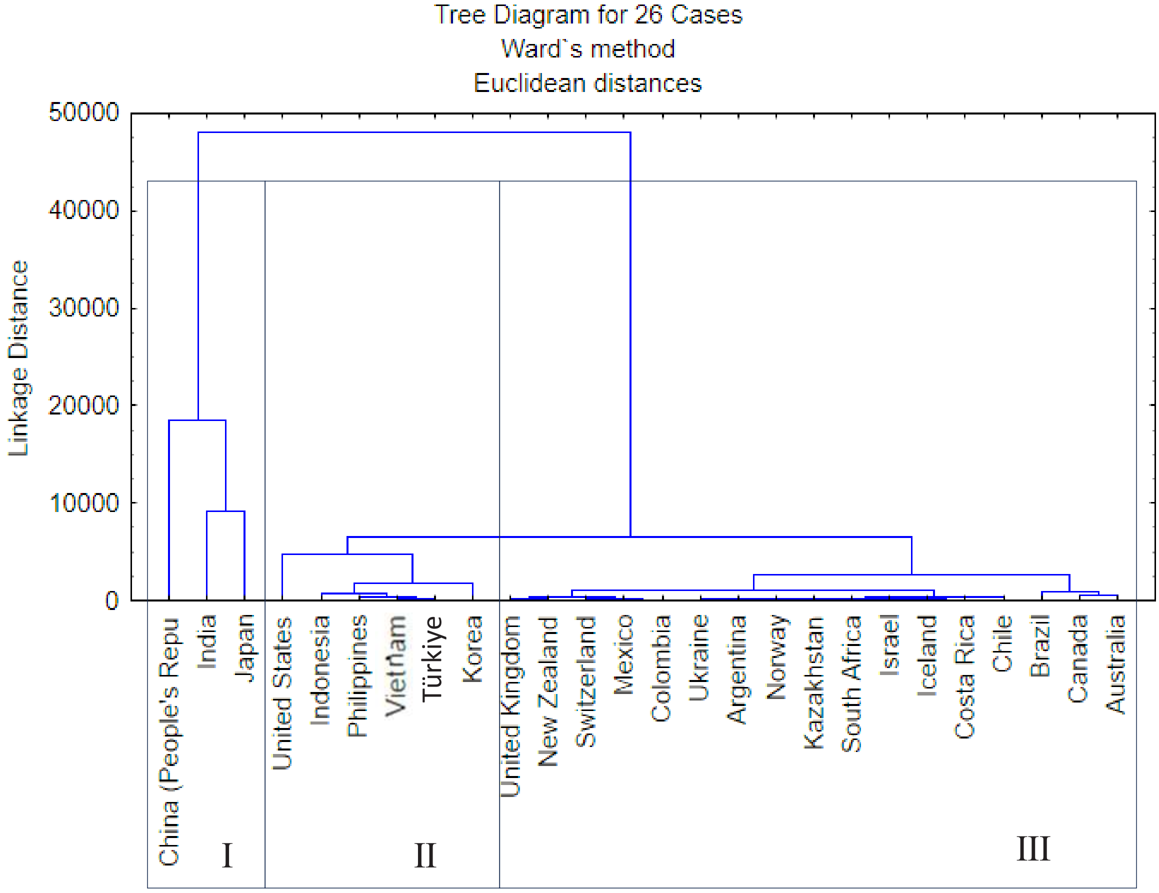

Figure 3. Dendrogram of the redistribution of countries between clusters according to the Ward method with GSSE4 and GSSE6 indicators excluded

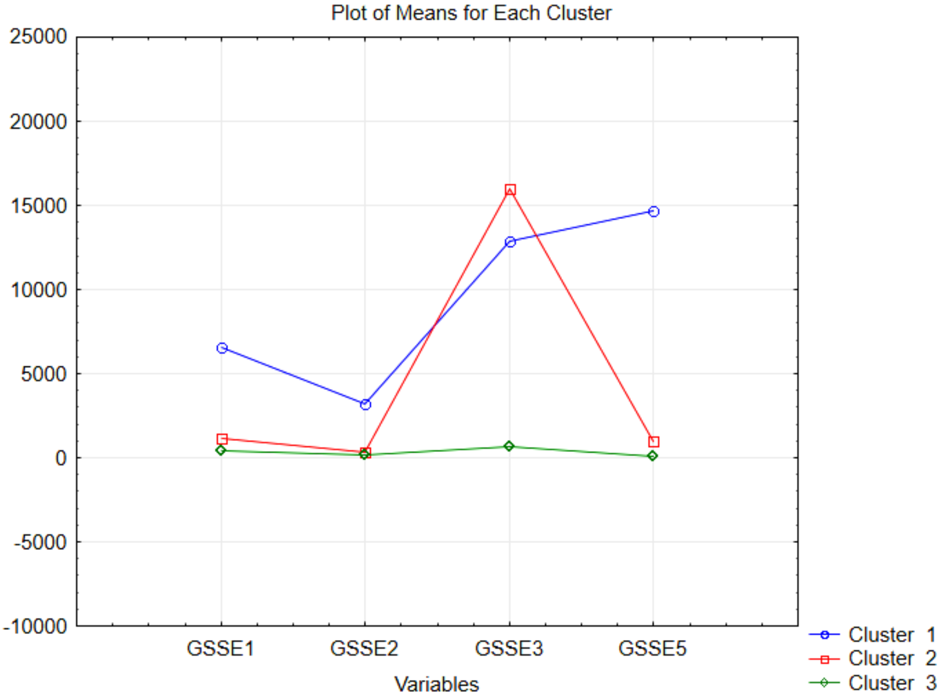

Figure 4. Average values of indicators GSSE1-GSSE3 and GSSE5 within selected clusters by k-means clustering method

Table 3. Variance analysis excluding GSSE4 and GSSE6

Indicator	Between SS	df	Within SS	df	F	p-value
GSSE1	35844680.0	2.0	9268606.0	23.0	44.5	0.000
GSSE2	8746825.0	2.0	1815716.0	23.0	55.4	0.000
GSSE3	353002800.0	2.0	47846480.0	23.0	84.8	0.000
GSSE5	204991000.0	2.0	473878.8	23.0	4974.7	0.000

Due to the excluded indicators, the structure of the clusters has slightly changed – the USA moved from the first to the second cluster.

The first cluster now includes only Asian countries, which show the highest values of the clustering indicators (Figure 5).

China is the undisputed leader in this cluster, with the highest investments in the agricultural knowledge and innovation system (6,529.7 million USD), inspection and control (3,177.9 million USD), development and maintenance of infrastructure (12,874.7 million USD), and the cost of public stockholding (14,668.5 million USD). India stands

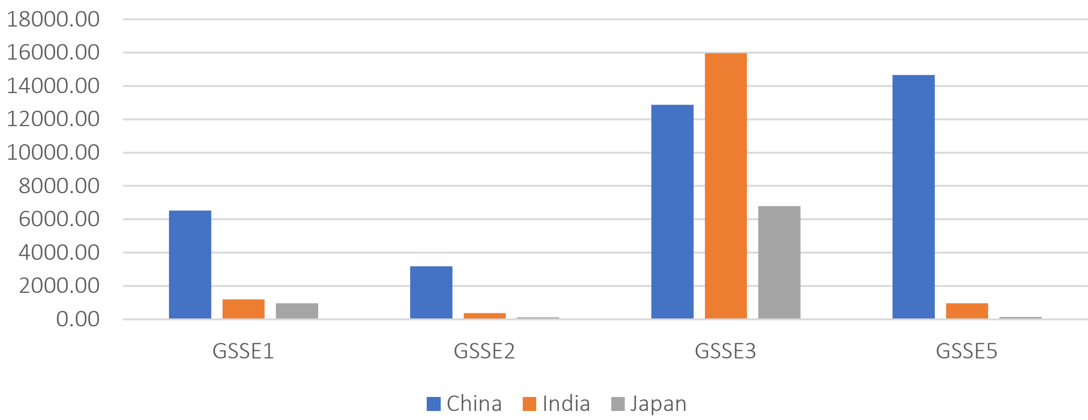

Figure 5. Clustering GSSE1-GSSE3 and GSSE5 indicators for the countries included in the first cluster

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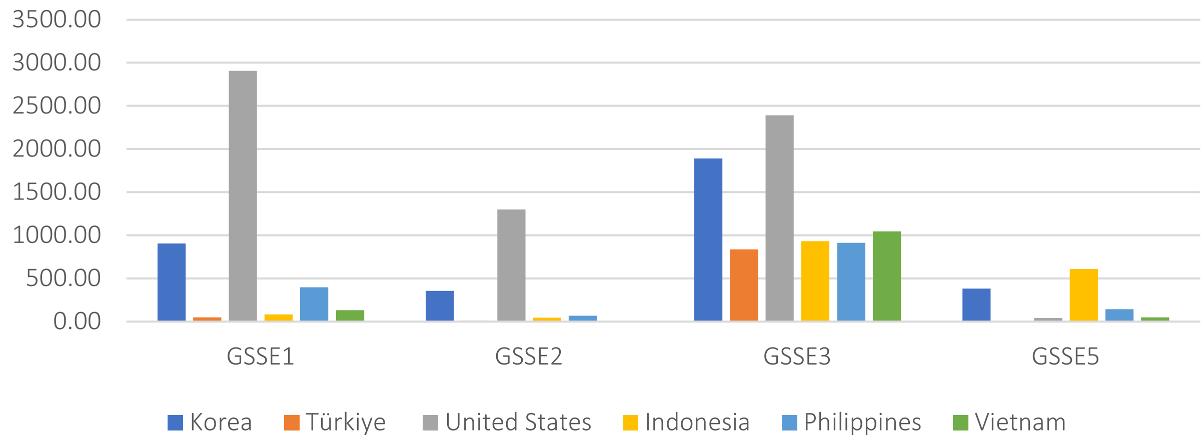

Figure 6. Clustering GSSE1-GSSE3 and GSSE5 indicators for countries included in the second cluster

out not only in the first cluster but also among all other countries studied, with the highest value for the development and maintenance of infrastructure (15,966.9 million USD). It is noteworthy that Japan also shows a significant level of investment in the development and maintenance of infrastructure (6,789.6 million USD), yet it has the smallest values compared to India and China for inspection and control (121.1 million USD) and the cost of public stockholding (129.6 million USD).

The second cluster comprises countries with a medium level of clustering indicators (Figure 6).

Among the countries that entered this cluster, the United States clearly holds a leadership position. For three of the four clustering indicators, the USA shows the highest values (the share of agricultural knowledge and innovation system – 2,908.4 million USD, the share of inspection and control – 1,298.0 million USD, the share of development and maintenance of infrastructure – 2,392.5 million USD), while the share of cost of public stockholding (39.9 million USD) is the lowest in this cluster. Korea ranks second in this cluster after the USA, showing significant values for the first three indicators. Türkiye is the outlier of this cluster with the minimum values for three indicators except for the share of development and maintenance of infrastructure (835.6 million USD). Overall, all countries in the second cluster demonstrate a positive dynamic of this indicator.

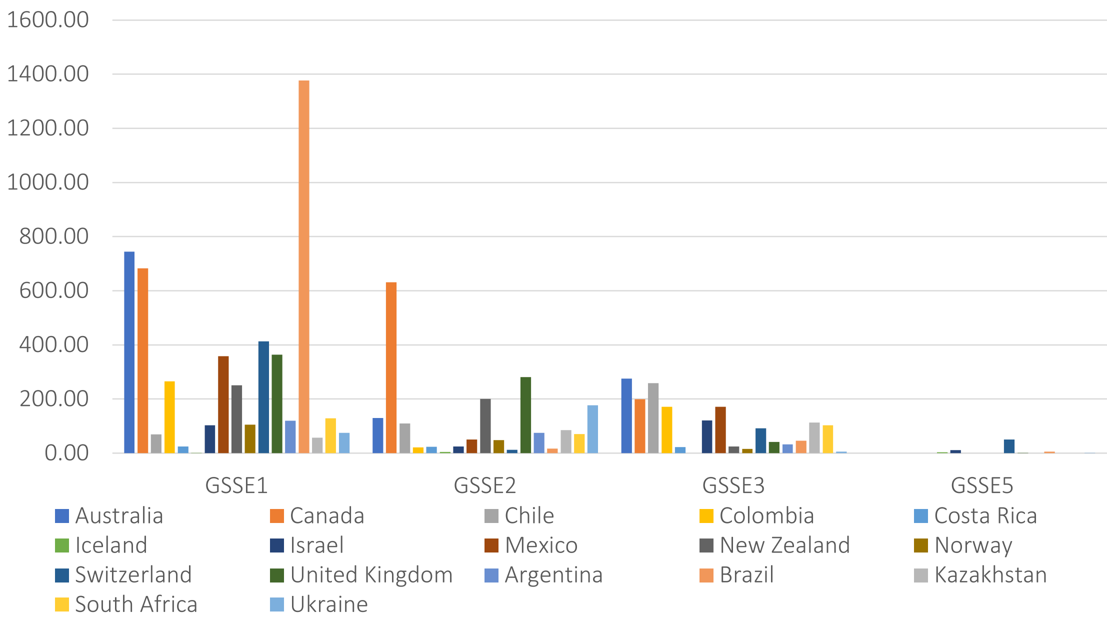

Figure 7. Clustering GSSE1-GSSE3 and GSSE5 indicators for countries included in the third cluster

The third cluster is the largest in terms of the number of countries included. However, the values of the clustering indicators here are the lowest (Figure 7). It is impossible to single out one leader among the countries of this cluster for all clustering indicators. However, Canada shows a positive dynamic, having the highest value in the cluster for the share of inspection and control (631.8 million USD) and the second highest value after Australia (744.6 million USD) for the share of agricultural knowledge and innovation system (683.1 million USD). Brazil shows a rather weak position in this cluster except for the value of the share of agricultural knowledge and innovation system (1,376.8 million USD), which is the highest in the cluster. At the same time, Brazil is at the lowest level for the other three clustering indicators.

In the structure of the third cluster, Ukraine, based on the values of the clustering indicators, is on par with Kazakhstan, Argentina, and Israel.

4. DISCUSSION

Supporting the agricultural sector is naturally recognized as critically important for the economies of many countries worldwide, ensuring food security, socio-economic development, and resilience to climate change. Thus, Chalajour and Nashroodkoli (2022) focus on the analysis of agricultural sector support policies in OECD member countries, Kułyk (2019) and Belinska et al. (2021) – in EU countries to review essential changes in current policies, assessments, and recommendations in this field. These works point to the need to reorient aid in stimulating sustainable development, including measures to stabilize incomes and profits, which require a careful assessment of their effectiveness and impact on taxpayers. DeBoe (2020) emphasizes that agricultural policy has complex effects on the environmental sustainability and productivity of the agricultural sector, depending on the type of policy, local conditions, and farmers' responses to economic incentives. Understanding these nuances is essential to forming effective policies that balance supporting the agricultural sector and preserving the environment.

While determining business practices in agriculture, the emphasis of this study is shifted toward financial support of agricultural knowledge and innovation systems, inspection and control, development and maintenance of infrastructure, and cost of public stockholding, which allows approaching this issue from a cost point of view. At the same time, according to Ackermann et al. (2018), the methodology for measuring agricultural support policies has two assumptions that involve either an underestimation or an overestimation of support to farmers, which should also be considered when analyzing the limitations of this work.

Vankovych et al. (2020) analyzed the effectiveness of the state agricultural policy of Ukraine and its impact on agribusiness, stressing the shortcomings of using budget funds intended to support the agricultural sector. The authors criticize the primary mechanism of state support, which consists of direct budget payments to agricultural producers, for its inefficiency and lack of adaptation to the specific conditions of Ukraine. They point to a weak connection between significant budgetary infusions into the agricultural sector and the limited effect of their use, which does not allow the current support mechanism to be considered adequate. It is recommended that the support of agribusiness in Ukraine should not aim to reduce intermediate consumption but at budgetary payments (tax benefits) related to the production of certain types of products or parameters of farming, as well as at budgetary financing of agricultural development. In contrast, this paper found that countries with a high level of financial support for agricultural knowledge and innovation systems, inspection and control, development and maintenance of infrastructure (China, India, Japan, the USA, and Canada) ensure successful business practices in the sector agriculture and can be an example for other countries to follow.

Wong et al. (2023) open new perspectives for understanding the relationship between government policy and its impact on agricultural production using the example of Latin American countries, which also affects cluster associations of countries. The results show that an increase in the total assessment of support and support of market prices, which constitute a significant share of total costs, increases greenhouse gas emissions. In contrast, when the total estimate of service support is a larger share, emissions decrease. It emphasizes

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the importance of reorienting the support of the agricultural sector in the direction of sustainable development and reducing the impact on the environment. In contrast, this work revealed that a significant share of the General Services Support Estimate of the agricultural sector falls precisely on industrially powerful countries, where environmental issues need to be resolved.

CONCLUSION

The goal of the study is to cluster countries worldwide by business practices in the agricultural sector, which can reveal general trends and specifics in the application of sustainable methods in agricultural business management. Thus, the study identified three clusters.

Countries of the first cluster are characterized by an orientation toward business practices that involve high investments in innovation and scientific research. These countries emphasize the use of advanced technologies and research to increase productivity and efficiency. China, as a leader, shows the share of agricultural knowledge and innovation system – 6,529.7 million USD, the share of inspection and control – 3,177.9 million USD, the share of development and maintenance of infrastructure – 12,874.7 million USD, and the share of cost of public stockholding – 14,668.5 million USD.

The second cluster demonstrates business-oriented practices that provide leadership in innovation, control, and infrastructure development but have low public stockholding rates, which may indicate a greater reliance on the private sector to ensure sustainable food security. The USA is the leader (the share of agricultural knowledge and innovation system – 2,908.4 million USD, the share of inspection and control – 1,298.0 million USD, and the share of development and maintenance of infrastructure – 2,392.5 million USD).

Countries of the third cluster demonstrate positive dynamics of business practices in inspection and control and investments in agricultural knowledge and innovation. It indicates the strategic orientation of their business practices on product quality and safety, innovation, and scientific research. Canada is a leader of this cluster (the share of inspection and control – 631.8 million USD and the share of agricultural knowledge and innovation system – 683.1 million USD).

The analysis not only emphasizes unique strategies for developing the agricultural sector in countries with different economic conditions but also points to potential directions for the optimization and integration of global agricultural practices. The value of the study lies in providing a strategic overview that can serve as a basis for developing policies that can increase food security, sustainability, and innovative development of the agricultural sector at the international level.

AUTHOR CONTRIBUTIONS

Conceptualization: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna, Oleksandr Tkachenko.
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Investigation: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna.
Methodology: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko.
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Supervision: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna, Oleksandr Tkachenko.
Validation: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko.

Visualization: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna, Oleksandr Tkachenko.
Writing – original draft: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna, Oleksandr Tkachenko.
Writing – review & editing: Olena Dobrovolska, Knut Schmidtke, Pavlo Lastovchenko, Olga Odnoshevna, Oleksandr Tkachenko.

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