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Algorithm for Selecting Alternative Strategies for Sustainable Intensification of Agricultural Enterprises

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Abstract. Growing food shortage encourage businesses to increase yields, mainly through extensive capacity building. However, this path often leads to a negative impact on the environment and does not consider social issues. Increasing yields requires the implementation of strategies for sustainable agricultural development and intensification of production. Selecting such strategies at the level of agricultural enterprises requires their classification and analysis. The purpose of the study is to group agrarian enterprises in Kharkiv Oblast and identify clusters with high potential for the implementation of alternative strategies for sustainable intensification. Based on the concept proposed by J. Pretty, the study classifies enterprises by the ecological and economic, socio-economic and environmental dimensions on the basis of such factors as crop diversity, depreciation, organic fertiliser application, labour costs, use of mineral fertilisers, fuel materials per hectare of land. Data from 514 agricultural production enterprises in Kharkiv Oblast in 2019 and 510 enterprises in 2020 were used for the categorisation. The data were processed through a cluster analysis method using specialised Microsoft Excel and SPSS21 software. The study presents an algorithm for choosing strategies for sustainable development and sustainable intensification of agricultural enterprises based on cluster analysis. Classification of enterprises by the level of diversity of agricultural crops, application of organic fertilisers, labour costs, application of mineral fertilisers, depreciation level, fuel materials per hectare of land allowed identifying agricultural enterprises that have the greatest potential to implement sustainable intensification practices from the proposed alternatives. The introduction of integrated pest management tools has been suggested for companies that consume significant amounts of mineral fertilisers and fuels and lubricants. The practical significance of the findings lies in providing recommendations for selecting sustainable intensification strategies depending on the level of enterprise yields, the amount of mineral fertiliser and fuel and lubricants used, the diversity of crops, etc.

Keywords: sustainable development, sustainable development strategies, cluster analysis, one-way ANOVA, agriculture, Kharkiv Oblast

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Introduction

One of the most important strategies for economic growth is the development of the agricultural sector, which is the main source of income for a significant number of households, and also provides a significant part of Ukraine's exports, 26.6% of which are products of animal and plant origin [1]. Agriculture accounts for 9.3% of the country's gross domestic product (GDP) [2]. Although this sector constitutes a small part of GDP, it is considered one of the most important sectors in terms of employment and food supply. Agriculture offers employment for almost 20% of the active population and creates a significant export potential for the agro-industrial complex and food industry, which amounted to 45.1% in 2020 [3]. In addition, Ukraine's deeper integration into global economic processes requires increasing its capacity to ensure food security. In fact, by 2050 food production may need to increase by 60-110% in order to feed the growing world population [4]. At the same time, in many developing countries, including Ukraine, the expansion of production comes at the expense of extensive use of natural resources, reduced agricultural diversity, accompanied by a decline in opportunities and employment. This requires strategies to intensify agricultural production. The rationale for intensification has been well formulated in the literature, both in terms of increasing production through the cultivation of high-yielding crops, increasing irrigation, mechanization and use of chemicals, and in terms of preserving millions of hectares of forests and about 590 billion tons of CO_2, which could not be released into the atmosphere [5]. A growing number of studies demonstrate that sustainable agricultural practices can increase productivity (yield) and meet sustainability dimensions [6].

Therefore, the government of the country faces an urgent issue of agribusiness development through the constant intensification and implementation of strategies for the sustainable development of agricultural enterprises [7]. The importance of sustainable agriculture lies not only in ensuring ecological balance but also in taking into account the values of the environment and society [8].

Strategies for achieving the sustainable development goals are being adopted at the national level. An example is the Sustainable Development Strategy 2030 in Ukraine [9]. The main aspect of its development was to incorporate the 2030 Sustainable Development Goals adapted for Ukraine and the main provisions of the EU's annual Sustainable Growth Strategy [10]. However, the issue of developing and implementing sustainable development strategies at the enterprise level remains equally important. The search for alternative strategies for sustainable development at the level of agricultural enterprises requires, first of all, their classification [6].

In any realistic assessment of the constraints and opportunities that economic actors can exploit, typology is an important step [11]. Typology studies can be used to analyse factors affecting the productivity of agricultural enterprises, determine the potential for sustainable intensification practices, and identify opportunities and constraints for implementing development strategies. Provided a database is available, multivariate statistical methods make it possible to find such typologies based on the concept of stable intensification and its factors identified in previous studies. In one of his first works, J. Pretty suggested that continuous intensification should be considered in the context of increasing output without harming the environment [12]. The team of authors further analysed the possibilities of redesigning the agro-system to introduce specific practices for sustainable production and increase its volume [13]. Case studies on agricultural intensification and the factors identified in different countries can be found in [4; 14; 15]. At the same time, researchers have identified factors for the sustainable intensification of agriculture in Ukraine in the ecological and economic, socio-economic, and ecological dimensions [7].

The purpose of the study is to group agrarian enterprises in Kharkiv Oblast according to pre-determined factors and identify clusters with high potential for the implementation of alternative strategies for sustainable intensification.

Materials and Methods

To achieve this goal, the study clustered enterprises by factors of constant intensification using the k-means clustering method. In particular, the grouping was based on the level of crop diversity, application of organic fertilisers, labour costs, use of mineral fertilisers, depreciation, use of fuel materials per hectare of land [7]. Cluster analysis was conducted with the data for the years 2019 and 2020 for 514 and 510 enterprises, respectively, engaged in agricultural activities in Kharkiv Oblast.

The clustering method was chosen primarily for its ease of use and informative content compared to hierarchical methods [16]. However, determining the most appropriate number of clusters required the use of a hierarchical method and a distribution method [17].

The approach of J. Lattin et al. was applied, according to which the k-cluster solution can be found by combining two clusters from the k+1 cluster solution, while at the same time the distribution method classified agricultural enterprises into a certain number of clusters [18]. To find the best solution for a cluster, Ward's hierarchical procedure was used to minimise changes in each cluster and identify clusters of the same size [19]. The solution was achieved by finding the number of clusters based on the change between the distance coefficient at one clustering stage and the previous one. Clusters of the best solutions were further analysed using the k-means clustering method for the most realistic final solution.

As a result, four clusters of agricultural enterprises were formed based on a set of indicators for the 2019 data and three, four and five clusters for the 2020 data in the context of the socio-economic, ecological, and economic and environmental dimension respectively. As a result, the k-means found the most realistic and significant final solution, followed by one-way analysis of the variance test, demonstrating the significance of the results (<0.001). The cluster analysis method was carried out using the SPSS21 software package.

Results and Discussion

The algorithm for selecting alternative strategies for sustainable development and sustainable intensification of agricultural enterprises based on cluster analysis is shown in Figure 1.

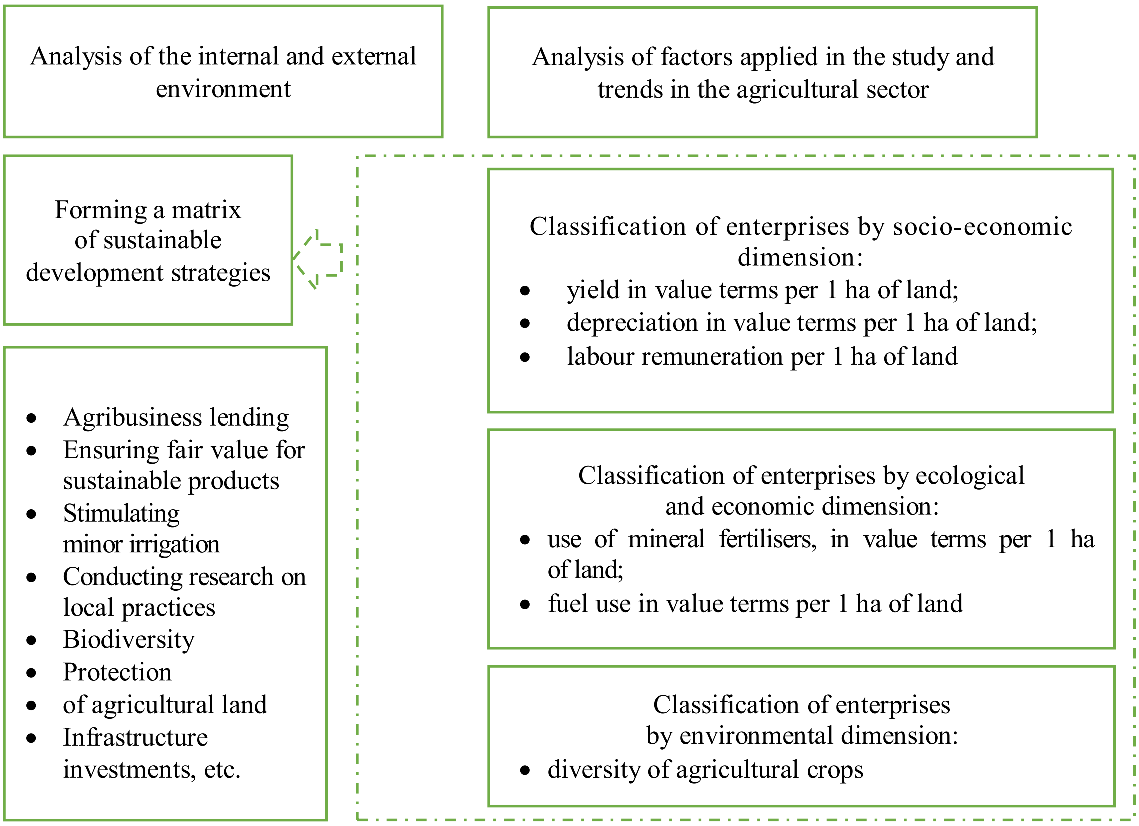

Figure 1. Algorithm for selecting alternative strategies for sustainable intensification of agricultural enterprises
Source: compiled by the author based on [12]

For each of the three dimensions, a certain number of enterprises (within 1-2% of the total population) do not fall into any cluster. In particular, in 2019, clustering covered 98% of observations (504 observations for the socio-economic dimension, 506 observations for the ecological and economic dimension and 507 observations for the environmental dimension). Accordingly, in 2020, the cluster analysis explained mostly 99% of the observations (505, 507 and 505 respectively). Using the k-mean method, the best solution for classifying businesses by socio-economic dimension is to isolate the four clusters that show the lowest p-values for a one-way analysis of variance for each variable (Table 1). The lower p-value represents a more significant difference in the variable among the groups.

Table 1. Characteristics of the selected cluster statistics of one-way ANOVA by socio-economic dimension (2019), UAH per 1 ha of land

Factors	Cluster 1 N=235	Cluster 2 N=56	Cluster 3 N=4	Cluster 4 N=209	F-dimension	P-value
Socio-economic dimension of clustering						
Yield	11963	31480	72100	19470	490.419	<0.001
Standard deviation	3071	5840	14210	2691		
Depreciation	1109	2020	1934	1659	578.704	<0.001
Standard deviation	1084	1583	1214	1332		
Labour Remuneration	1329	1174	3465	1248	299.041	<0.001
Standard deviation	1325	1209	3947	1151		
Other factors of sustained intensification						
Use of mineral fertilisers	2266	5319	6022	3474	–	–
Standard deviation	1400	3171	5079	1618		
Use of fuels	1835	4068	6863	2034	–	–
Standard deviation	1157	5094	2841	1159		
Number of crops cultivated	4.2	4.3	4	4.5	–	–
Standard deviation	1.7	1.7	0.81	1.82		

Source: compiled by the author based on data from enterprise financial statements [6]

Cluster 1 is characterised by the lowest yield, average depreciation and remuneration. However, enterprises of this type consume fewer resources to produce agricultural products compared to other clusters. The higher values of Cluster 4, and greater yields resulted in a slightly increased consumption of resources. Enterprises in Cluster 2 are the least efficient, as wages are low and the cost of fertiliser and fuel and lubricants used is slightly lower than in Cluster 3 The average yield of the latter is UAH 72,100 per 1 ha of land, which exceeds the yield of Cluster 2 enterprises by more than 2 times. At the same time, enterprises are resource-intensive.

According to the ecological and economic dimensions, enterprises were also divided into 4 clusters (Table 2).

Table 2. Characteristics of the selected cluster statistics of one-way ANOVA by ecological and economic dimension (2019), UAH per 1 ha of land

Factors	Cluster 1 N=311	Cluster 2 N=60	Cluster 3 N=118	Cluster 4 N=17	F-dimension	P-value
Ecological and economic dimension of clustering						
Use of mineral fertilisers	2080	3360	5095	9080	208.015	<0.001
Standard deviation	837	955	1305	3605		
Use of fuels	1560	4078	1952	6660	483.583	<0.001
Standard deviation	636	1238	670	3176		
Other factors of sustained intensification						
Yield	15286	20853	19435	34563	–	–
Standard deviation	6200	11421	5707	16929		
Depreciation	1284	2337	1540	2400	–	–
Standard deviation	1160	2627	1268	1755		
Labour Remuneration	1175	3068	1065	3007	–	–
Standard deviation	1019	4078	874	5174		
Number of crops cultivated	4.4	4.63	4.1	4.1	–	
Standard deviation	1.69	1.92	1.85	1.59		

Source: compiled by the author based on data from enterprise financial statements [6]

Cluster 1 enterprises are the least resource-intensive, but yields, remuneration, and depreciation are significantly lower compared to other clusters. Cluster 2 and Cluster 3 show low efficiency, as enterprises have slightly higher yields than those in Cluster 1, but their operations require significant resources. Cluster 4 enterprises are resource-intensive. The last dimension, the number of crops cultivated, has demonstrated that crop diversity increases yield under equal other conditions. Enterprises that cultivate three basic and highly profitable crops in Kharkiv Oblast such as wheat, maize and sunflower have high yields (Table 3).

Table 3. Characteristics of the selected cluster statistics of one-way ANOVA by ecological dimension (2019), UAH per 1 ha of land

Factors	Cluster 1 N=201	Cluster 2 N=208	Cluster 3 N=19	Cluster 4 N=79	F-dimension	P-value
Ecological dimension of clustering						
Number of crops cultivated	5.6	3.6	8.4	1.8	931.883	<0.001
Standard deviation	0.8	0.5	0.5	0.4		
Other factors of sustained intensification						
Use of mineral fertilisers	3095	3119	3484	3630	–	–
Standard deviation	1949	1990	2242	2335		
Use of fuels	2128	2436	2323	2099	–	–
Standard deviation	1300	3020	1059	2685		
Yield	17530	18051	18943	16643	–	–
Standard deviation	7286	10072	6163	7767		
Depreciation	1647	1285	1840	2662	–	–
Standard deviation	1295	1233	1544	9430		
Labour remuneration	1555	1388	1978	1582	–	–
Standard deviation	1629	2236	1600	4858		

Source: compiled by the author based on data from enterprise financial statements [6]

Furthermore, a cluster analysis based on 2020 data was carried out and three clusters were identified according to the socio-economic dimension (Table 4). Compared to 2019, the cluster with the highest yields (in 2020 – Cluster 1) showed a higher performance of enterprises, but the consumption of mineral fertilisers and especially of fuels and lubricants also increased. At the same time, Cluster 3 enterprises have the greatest potential for sustainable intensification of economic activity. Cluster 2 contains enterprises with the lowest yield.

Table 4. Characteristics of the selected cluster statistics of one-way ANOVA by socio-economic dimension (2020), UAH per 1 ha of land

Factors	Cluster 1 N=23	Cluster 2 N=290	Cluster 3 N=192	F-dimension	P-value
Socio-economic dimension of clustering					
Yield	74156	16814	31800	896.462	<0.001
Standard deviation	13080	4786	6227		
Depreciation	2263	1051	1733	148.793	<0.001
Standard deviation	1662	1063	1350		
Labour Remuneration	5649	967	1498	148.793	<0.001
Standard deviation	5474	787	1324		
Other factors of sustained intensification					
Use of mineral fertilisers	6271	2624	3746	–	–
Standard deviation	8573	2826	2155		
Use of fuels	8156	1534	2384	–	–
Standard deviation	9935	1372	3288		
Number of crops cultivated	5.43	5.33	5.88	–	–
Standard deviation	2.35	2.17	2.49		

Source: compiled by the author based on data from enterprise financial statements [6]

According to the ecological and economic dimension, 4 clusters were also obtained, as in the 2019 data (Table 5). Enterprises in Cluster 3 with significant consumption of minerals and Cluster 4 with increasing costs of fuel and lubricants are inefficient. Clusters 1 and 2 have the potential for sustained production intensification, although the yield is lower compared to other clusters. Cluster 3 needs to reduce the consumption of mineral fertilisers.

Table 5. Characteristics of the selected cluster statistics of one-way ANOVA by ecological and economic dimension (2020), UAH per 1 ha of land

Factors	Cluster 1 N=201	Cluster 2 N=249	Cluster 3 N=45	Cluster 4 N=12	F-dimension	P-value
Ecological and economic dimension of clustering						
Use of mineral fertilisers	3649	1686	7457	7680	1355.510	<0.001
Standard deviation	787	708	1532	4269		
Use of fuels	2089	1333	2963	18247	805.962	<0.001
Standard deviation	1088	678	1252	11055		
Other factors of sustained intensification						
Yield	29184	20139	31997	69990	–	–
Standard deviation	16871	8621	21236	69992		
Depreciation	1715	1117	1675	6251	–	–
Standard deviation	1324	1095	1326	9788		
Labour Remuneration	1643	1108	1197	6965	–	–
Standard deviation	1944	951	1460	13239		
Number of crops cultivated	5.9	5.48	4.95	3.75	–	
Standard deviation	2.35	2.28	2.23	1.54		

Source: compiled by the author based on data from enterprise financial statements [6]

In terms of the number of crops cultivated, yields increase with greater diversity, which is a positive sign for sustainable production (Table 6). Clusters 3 and 4 are optimal in terms of resource consumption and yield. At the same time, Cluster 5 enterprises have the highest yield, since they only cultivate one or two agricultural crops that generate the greatest profitability (corn, wheat, sunflower), and depend significantly on mineral fertilisers. Enterprises in Cluster 1 and Cluster 2 provide the lowest labour remuneration and lower yields compared to other clusters.

Table 6. Characteristics of the selected cluster statistics of one-way ANOVA by ecological dimension (2020), UAH per 1 ha of land

Factors	Cluster 1 N=125	Cluster 2 N=265	Cluster 3 N=32	Cluster 4 N=57	Cluster 5 N=26	F-dimension	P-value
Ecological dimension of clustering							
Number of crops cultivated	6.53	4.09	10.5	8.4	1.58	1164.5	<0.001
Standard deviation	0.5	0.77	0.5	0.5	0.64	–	–
Other factors of sustained intensification							
Use of mineral fertilisers	3039	3296	2929	2584	11054	–	–
Standard deviation	2098	2111	1477	1340	15602	–	–
Use of fuels	1844	2465	2153	1839	6209	–	–
Standard deviation	1426	4142	865	895	6106	–	–
Yield	26585	24496	28000	27616	39656	–	–
Standard deviation	17123	20031	11656	15341	41262	–	–
Depreciation	1525	1317	2062	1810	2650	–	–
Standard deviation	1336	1553	1481	1451	6463	–	–
Labour Remuneration	1398	1133	2850	2101	2620	–	–
Standard deviation	1229	3001	1850	2141	4185	–	–

Source: compiled by the author based on data from enterprise financial statements [6]

The cluster analysis allowed identifying groups of enterprises with significant potential for sustainable intensification for each dimension. In 2020, the number of such enterprises increased. According to the socio-economic dimension – 192 enterprises, ecological and economic dimension – 450, ecological dimension – 89. For such enterprises, it is proposed to use various alternative strategies for sustainable production intensification (Table 7). The analysis also considers the results of previous studies, which show that yields can be reduced when changing from conventional to more sustainable farming practices [5].

Table 7. Strategies for sustainable intensification of agricultural enterprises

Development strategies	Application / implementation
Agribusiness lending	Sustainable production requires the transfer of technology and its acquisition, in turn, requires adequate funding
Ensuring fair prices for sustainable products	Creating conditions for maintaining fair prices Formation of non-traditional commodity markets and direct sales markets (via farmers' markets and/or the Internet); obtaining premiums with marked features (e.g., organic, naturally raised livestock), increasing participation in value chains
Soil conservation (land cultivation)	Sustainable agriculture consists of a group of strategies aimed at minimising soil disturbance, maintenance of cover and crop rotations. Their realisation is possible with the accessibility of water, soil structure and biotic activity. Strategies are almost never used by small businesses, which often meet the need for food products locally and cannot afford the transition period
Conducting research on local practices	Short-term local studies of biodiversity and sustainable practices, the impact of their implementation. Today, commercial varieties are mainly characterised by herbicide resistance and pest resistance. Some other traits have been introduced to provide the nutritional benefits of food
Diversity of agricultural crops	Incentives for farmers to produce diversified crops (more than 50% of the analysed enterprises grew 6 or more crops in 2020), apply crop rotations
Infrastructure investments	Reduce costs, including marketing costs, related to damage and other factors. Development of social infrastructure
Agricultural research	More and more farmers are willing to use fertilisers containing micro-nutrients such as gypsum, zinc sulphate and borax and to use siderates.
Irrigation expansion	Bringing more land under irrigation will create employment opportunities, help produce more food and generate income
Provision of mineral fertilisers	The import and distribution of fertilisers remain under the control of private companies, and prices are adjusted depending on the competition. The government should establish rules to ensure proper labelling of fertiliser containers; also encourage the production and sale of mixed fertilisers

Table 7, Continued

Development strategies	Application / implementation
Use of mineral fertilisers	Most of the enterprises in question demonstrate unbalanced use of fertilisers and excessive use of pesticides, leading to environmental concerns such as soil acidification, pest attacks, water pollution and deteriorating health conditions. At the legislative level, restrictions should be imposed on the import, distribution, labelling and use of chemicals
Economic regulation	A national revenue accounting system should take into account the true value of natural resources to avoid over-exploitation
Implementation of integrated pest management	Integrated pest management means planning pesticide applications based on monitoring and setting economic thresholds
Development of alternative energy sources	Government programmes to encourage the production and use of alternative energy sources through "green tariffs", etc.
Introducing environmental services	Development of compensation programmes for loss of profits due to the introduction of new practices or environmental services (intensity of tillage, soil use, crop diversity, level of plant protection, etc.).
Development of agricultural education	Establish broad, system-oriented training in agriculture; support vocational training to increase farmers' profits

Source: compiled from materials [21-24]

The cluster analysis also showed that the implementation of integrated pest management (IPM) is particularly important in enterprises that use significant amounts of mineral fertilisers and pesticides to maintain high crop yields. Excessive dependence on agrochemicals as the only form of plant protection is not a sustainable and effective practice [20]. Pest management consists of a set of tools for making managerial decisions and measures aimed at combining the use of targeted compounds, as well as agronomic and biological methods of crop pest control.

IPM strategies evolved from local practices to coordinated community-based decision-making. The experience of implementing IRM at individual agricultural enterprises in 26 developing countries has shown four possible scenarios of changes in the volume of chemicals used and yields, in particular: 1) an increase in the use of pesticides is accompanied by an increase in yield; 2) the use of pesticides increases, but the yield decreases; 3) a decrease in the use of pesticides is accompanied by a decrease in yield; 4) the use of pesticides decreases, but the yield increases [12]. More than 60% of the projects were in the category where pesticide use decreased and yield increased.

One of the most efficient and quickly adopted IPM systems is push-pull, which demonstrates significant success with the redesign of the monocrop crop system [25]. A promising direction is the introduction of systems to improve varieties [13], nutrient content, resource efficiency and the reduction of greenhouse gas emissions [26]. Variety development is also necessary to produce perennials with desirable traits such as larger seed size, stronger stems, improved palatability and increased yield [14] Breeding plants with deeper and shrubby root systems can help improve soil structure, absorb water and carbon, retain nutrients, and produce higher yields.

Thus, sustainability in agriculture means applying practices that allow preserving natural resources by eliminating extensive farming methods and using chemicals in significant volumes [27]. On the other hand, sustainable agriculture can be seen from a social standpoint as the ability to respond to the growing demand for food [28]. Sustainability can also be observed in the processes of a business model that functions according to a circular economy [25]. Such a business model offers alternative management methods that are less resource-intensive but provide the necessary level of profitability [14].

The concept of sustainability, known as the triple bottom line (TBL), involves balancing 3P's (planet, people, and profit). The concept of sustainable business (sustainable enterprise) has additional aspects, namely 3E (ethics, efficiency, and effectiveness). This concept is called the triple top line (TTL) [29]. The combination of both concepts prompted further exploration of different dimensions for sustainability in the environment, and social and economic aspects of the enterprise. At the same time, sustainable business needs to design and implement appropriate balanced development strategies in the framework of the combined dimensions. Therefore, there is a strong argument for the adoption of sustainable intensification of agriculture as a strategy to achieve the goals of the combined 3P and 3E concepts.

Conclusions

Based on a cluster analysis of the data, groups of agricultural enterprises similar to each other in terms of the set of time-varying factors were identified. To determine patterns, heterogeneity between clusters was studied using k-means, based on representative samples over 2019-2020. Thus, in 2020, agricultural enterprises in Kharkiv Oblast were increasingly expanding the number of crops, raising costs for depreciation, labour and mineral fertilisers. The developed algorithm for selecting alternative strategies for sustainable intensification of agricultural enterprises made it possible to select strategies for improving their agricultural potential using an approach that, unlike others, is based on comparing clusters of enterprises formed using sustainable intensification factors - the level of crop diversity, application of organic fertilisers, labour costs, use of mineral fertilisers, depreciation level, use of fuel materials per 1 ha of land area. The use of fertiliser compared to yield levels across clusters shows a directly proportional relationship in five of the six cases measured in different dimensions. Excessive use of fertilisers contaminates soils and causes repeated outbreaks of pests, potentially leading to long-term economic losses. Therefore, acquiring the knowledge on how to apply and implement sustainable intensification strategies, such as water, soil and nutrient management, will enable agricultural producers to invest some of the money saved from fertilisers in other inputs, such as top-quality seeds and inorganic fertilisers. The effects of the latter are the next potential area of investigation.

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Алгоритм вибору альтернативних стратегій сталої інтенсифікації аграрних підприємств

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Анотація. Зростаючі потреби у продуктах харчування спонукають підприємства до збільшення урожайності, здебільшого за рахунок екстенсивного нарощування потенціалу. Проте такий шлях нерідко призводить до негативного впливу на навколишнє середовище та не враховує соціальні проблеми. Збільшення врожайності потребує імплементації стратегій сталого розвитку сільського господарства та сталої інтенсифікації виробництва. Обрання таких стратегій на рівні аграрних підприємств вимагає їх класифікації та аналізу. Метою дослідження є групування аграрних підприємств Харківської області та виокремлення кластерів з найвищим потенціалом до впровадження альтернативних стратегій сталої інтенсифікації. Спираючись на концепцію, запропоновану Дж. Претті, в дослідженні було здійснено класифікацію підприємств у еколого-економічному, соціально-економічному та екологічному вимірах за такими факторами, як: рівень різноманіття сільськогосподарських культур, амортизації, внесення органічних добрив, витрати на оплату праці, застосування мінеральних добрив, паливних матеріалів на 1 га площі землі. Для групування було використано дані 514 підприємств Харківської області у 2019 році та 510 підприємств у 2020 році, що вирощували сільськогосподарську продукцію. За допомогою методу кластерного аналізу здійснено обробку даних з використанням спеціалізованих програм Microsoft Excel та SPSS21. У роботі представлено алгоритм обрання стратегій сталого розвитку та сталої інтенсифікації аграрних підприємств, спираючись на кластерний аналіз. Класифікація підприємств за рівнем різноманіття сільськогосподарських культур, внесення органічних добрив, витрат на оплату праці, застосування мінеральних добрив, рівня амортизації, використання паливних матеріалів на 1 га площі землі дозволила виокремити аграрні підприємства, що мають найбільший потенціал до впровадження практик сталої інтенсифікації із запропонованих альтернатив. Для підприємств, які споживають значні обсяги мінеральних добрив та паливно-мастильних матеріалів, запропоновано впровадження інструментів інтегрованого pest-менеджменту. Практична значущість отриманих результатів полягає у наданні пропозицій щодо вибору стратегій сталої інтенсифікації виробництва в залежності від рівня урожайності підприємств, обсягів застосування мінеральних добрив та паливно-мастильних матеріалів, різноманіття сільськогосподарських культур тощо

Ключові слова: сталий розвиток, стратегії сталого розвитку, кластерний аналіз, одностороння ANOVA, сільське господарство, Харківська область