INNOVATION AND SUSTAINABILITY
Volume 6, No. 3. 2026
ISSN 2786-5940, e-ISSN 2786-5959
Received: 15.04.2026; Revised: 18.08.2026;
Accepted: 24.09.2026; Published: 05.10.2026
Journal homepage: https://inns.com.ua/en

UDC 331.101.26:338.43:334.73(477)
DOI: 10.31649/vis/3.2026.08

Human potential formation in the context of cooperative ecosystem development: A strategy for sustainable economic recovery

Viktor Fedaka
Postgraduate Student
Odesa National University of Technology
65039, 112 Kanatna Str., Odesa, Ukraine
https://orcid.org/0009-0004-7298-9070

Nataliia Skrypnyk
PhD in Economic Sciences
Odesa Polytechnic National University
65044, 1 Shevchenko Ave., Odesa, Ukraine
https://orcid.org/0000-0003-1331-2698

Viktor Zamlynskyi*
Doctor of Economic Sciences, Professor
Odesa National University of Technology
65039, 112 Kanatna Str., Odesa, Ukraine
https://orcid.org/0000-0001-7642-2443

Abstract. The relevance of the study is due to the need to preserve and restore the human potential of Ukraine in the face of military challenges, demographic losses and the transformation of the agro-food sector as a strategic sector of the national economy into a stable cooperative ecosystem. Of particular importance is the search for effective mechanisms for reproducing human capital to ensure food security and sustainable development of territories. The purpose of the study was to substantiate the theoretical and methodological principles for assessing the human potential of the country, with an emphasis on the agri-food sector and the development of cooperative ecosystems as a strategic mechanism for its reproduction, under current socio-economic transformations. The methodological basis of the study was the systemic, structural-functional, comparative and economic-statistical approaches, as well as SWOT analysis, which allowed for a comprehensive assessment of the state, risks and prospects for the development of human potential. Conceptual modelling and the method of integral assessment were used to formalise the processes of its reproduction. It has been established that human potential is a key factor in the economic stability and competitiveness of the state in the conditions of war and post-war transformations. The dynamics of the human development index of Ukraine have been analysed and the negative impact of demographic losses, migration processes and structural imbalances on the qualitative characteristics of human capital has been identified. The level of healthcare financing has been assessed and its lag behind European standards has been determined. Ukraine's position in the global innovation environment has been studied and their significance for the reproduction of intellectual capital has been substantiated. The risks of loss of human potential as a result of war have been systematised and their impact on economic development has been assessed. A conceptual model for assessing the human potential of the agri-food sector has been developed, and the advantages, limitations, opportunities and threats to its development have been identified. The practical value of the results lies in the possibility of their use by state administration bodies, scientific institutions and agro-industrial sector entities in the formation of strategies for the restoration of human potential, the development of rural areas and ensuring the sustainable functioning of the agri-food system of Ukraine

Keywords: human capital; demographic transformation; labour potential; food security; socio-economic cohesion; institutional development; post-war reconstructions

Suggested Citation:
Fedaka, V., Skrypnyk, N., & Zamlynskyi, V. (2026). Human potential formation in the context of cooperative ecosystem development: A strategy for sustainable economic recovery. *Innovation and Sustainability*, 6(3), 8-23. doi: 10.31649/vis/3.2026.08.

*Corresponding author (zam.agrariy@gmail)

Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/)

Introduction

The formation and development of human potential under current conditions acquires strategic importance for Ukraine, going far beyond the scope of social policy and transforming into a key driver of ensuring national resilience, economic security, and long-term competitiveness. War-induced demographic losses, forced population displacement, employment disparities, social inequality, and territorial asymmetries are reducing Ukraine's labour force, while at the same time increasing the importance of the population's competence potential as a determining factor in reconstruction, technological renewal of production, and deepening European economic integration. The global course towards sustainable development, decarbonisation, greening of production and implementation of ESG principles increases the requirements for human capital as a factor of investor trust, reputational stability and business competitiveness. Achieving its modern quality is determined by digital and "green" competencies, innovation, professional mobility, environmental responsibility and the ability to continuously update knowledge. The ability of personnel to ensure resource efficiency, circularity of production and technological adaptability in conditions of military threats, structural changes and high uncertainty acquires particular importance and relevance for research.

Analysis of recent research and publications. E. Libanova (2025) examined the demographic transformation of Ukraine under war conditions, focusing on population losses, forced migration, and labour shortages in the context of long-term risks to sustainable economic recovery and human potential reproduction. At the same time, the study leaves open the question of how demographic recovery should be integrated with technological modernisation and structural transformation of the economy. A. Kolot (2025) examined the transformation of employment, labour relations, and human capital under the influence of digitalisation, technological change, demographic shifts, and global instability. The study argues that the traditional concept of labour resources is gradually being replaced by a competency-based model in which digital skills, adaptability, lifelong learning, and innovative potential become the main determinants of competitiveness, which requires further research in identifying practical organisational and economic mechanisms that will contribute to the formation and effective use of human potential in the context of post-war reconstruction and regional disparities. Alongside the strong potential for the development of human potential in Ukraine, current realities for its full realisation were also characterised (Ushenko & Kurochka, 2025) by the presence of related problematic aspects. Among the main ones were the significantly lower life expectancy of Ukrainians compared to average European indicators (for men – by 12-13 years, for women – by 3.6-5.9 years); a shorter duration of education (for men – by 1.5-2.5 years, for women – on average by 0.4-2.6 years); a significant lag in GDP per capita; and a growing need for social inclusion (Radkevych, 2025).

According to the Ministry of Social Policy of Ukraine, the average life expectancy at birth in Ukraine is 70.9 years for women and 57.3 years for men, with the World Bank projecting a potential increase to 80 years by 2050 under conditions of socio-economic stabilisation in the country. There are also significant gaps between Ukraine and EU countries in terms of lifestyle indicators. Ukraine has one of the lowest shares among the adult European population that abstains from alcohol consumption – 58.9% among women and 29.9% among men. The level of participation in regular physical activity among Ukrainians remained below desirable levels, reflecting broader health-related constraints that can negatively influence human development, workforce resilience, and socio-economic sustainability (Ukrainian Women's Fund, 2025). M. Nazarov & V. Kurytskyi (2024) identified the deterioration of socio-economic infrastructure under wartime conditions as a critical factor limiting human potential development and regional economic recovery. According to the authors, the restoration of educational, healthcare, transport, and social infrastructure is essential for strengthening labour potential, reducing migration losses, and creating favourable conditions for sustainable post-war development. V. Demydenko (2026) emphasised that the preservation and development of human potential in Ukraine increasingly depend on effective municipal and legal mechanisms capable of addressing migration challenges and demographic decline. Complementing this perspective, N. Shapa *et al.* (2025) highlighted the importance of employee motivation, organisational adaptability, and behavioural factors as key determinants of workforce resilience and human capital development under conditions of economic transformation. Together, these studies indicate that both institutional capacity and motivational mechanisms are critical prerequisites for strengthening human potential and supporting sustainable post-war recovery. The purpose of the article was to analyse the development trends of human potential in the agri-food sector and to determine the main directions for its recovery and sustainable development in the context of military, demographic, and socio-economic challenges.

Materials and Methods

The study was conducted within an interdisciplinary framework integrating the concepts of human capital theory, human development, and post-war economic recovery. The methodological approach combined economic analysis, comparative statistics, risk assessment, scenario modelling, and strategic management to evaluate the impact of military challenges on human potential development in Ukraine and the agri-food sector. The information base comprised official national and international statistical sources, including the State Statistics Service of Ukraine, the Ministry of Finance of Ukraine, Eurostat, the United Nations Development Programme (UNDP), the World Bank, the International Monetary Fund (IMF), the UNESCO Institute for Statistics, and the World Intellectual

Property Organization (2025) database. Additional evidence was obtained from peer-reviewed publications indexed in Scopus and Web of Science and analytical reports on demographic change, migration, labour markets, and post-war recovery.

Corporate financial performance was evaluated using comparative analysis of official enterprise statistics, whereas estimates of physical war damage were derived from the World Bank's Rapid Damage and Needs Assessment (RDNA) and applied as secondary descriptive data. A system approach was employed to identify the interrelationships among demographic, educational, healthcare, labour-market, innovation, and economic factors influencing human potential. A structural-functional approach was applied to develop the conceptual model of human potential formation and to determine the role of the agri-food sector in sustainable socio-economic development. Human potential was assessed using comparative statistical analysis, time-series analysis, and indicator analysis. The dynamics of the Human Development Index (HDI), life expectancy, healthcare expenditure, education and research expenditure, unemployment, gender equality, and innovation performance were analysed using official statistical data. Comparative analysis between Ukraine and the European Union enabled the identification of long-term development trends and structural constraints affecting human capital reproduction. Information on demographic losses and migration was used descriptively to characterise wartime risks rather than as independently estimated indicators. For a comprehensive assessment of the state and efficiency of human potential use, the Inclusive Development Index (IDI), the indicator of man-hours worked, as well as the share of profitable and unprofitable enterprises were used. These indicators were used to characterise, respectively, the level of inclusiveness of socio-economic development, the actual use of labour potential, and the financial performance of enterprises.

Potential GDP losses were estimated using an adaptation of Okun's law, which describes the relationship between unemployment dynamics and economic output:

$$Loss_t = GDP_t \cdot \backslash frac\{\beta \vdash (u_t\text{-}u_1 \dashv)\}\{100\}, \quad (1)$$

where *GDP* – nominal GDP of Ukraine, billion USD; U_t – actual unemployment rate, %; U_1 – natural rate of unemployment, %; β – Okun's coefficient (the coefficient value is taken at 2.5); $Loss_t$ – amount of GDP loss, billion USD.

The consequences of the military conflict were evaluated using a risk assessment methodology combining qualitative analysis and expert interpretation. Risks were classified according to their probability and expected impact on demographic processes, labour migration, education, healthcare, employment, and innovation development. The assessment of physical and economic damage caused by the war was based on internationally recognised secondary data, primarily the RDNA. Estimates of direct and indirect losses in the housing, healthcare, education, and social protection sectors were used descriptively, without independent recalculation, to characterise the scale of destruction affecting human potential.

The performance of human capital utilisation in the agri-food sector was evaluated through corporate financial indicator analysis based on data from the State Statistics Service of Ukraine for 2014-2024. The analysed indicators included gross operating income per employee, gross value added per employee, net profit per employee, return on personnel costs, the share of personnel costs in total operating costs, and enterprise profitability. These indicators were used to assess the economic efficiency of human capital utilisation within the sector. An integrated assessment approach was applied to evaluate human potential in the agri-food sector by combining demographic, labour-market, educational, innovation, and economic indicators. Following normalisation, the indicators were aggregated into an integral assessment using weighted coefficients reflecting their relative contribution to human potential development. To assess the risks of potential economic losses caused by unemployment, the study employed a scenario-based approach using three reference unemployment rates. The first scenario assumed a 5% unemployment rate, which was considered a benchmark for an efficiently functioning labour market. The second scenario was based on an unemployment rate of 8.6%, corresponding to the lowest empirical level observed in Ukraine during the period 2014-2024 and serving as a pre-war baseline. The third scenario applied a 10% unemployment rate as a conservative estimate reflecting existing structural constraints and labour market imbalances. The integral risk level (*R*) was defined as:

$$R = P \cdot I, \quad (2)$$

where *P* – the risk probability assessment (1-5); *I* – the risk assessment expected impact (1-5).

Strategic development priorities were identified using the SWOT analysis, which enabled the systematic evaluation of internal strengths and weaknesses alongside external opportunities and threats affecting human potential development under wartime and post-war recovery conditions. Cooperative ecosystems were considered as an institutional mechanism supporting human capital reproduction, social inclusion, employment generation, and territorial resilience; however, they were analysed conceptually rather than as an independent object of quantitative assessment. The reliability of the findings was ensured through methodological triangulation, cross-validation of official national and international datasets, consistency checks across statistical indicators, and the application of generally accepted methods of economic and statistical analysis.

Results

The issue of developing human potential is of particular importance in the context of Ukraine's strategic course toward integration into the European Union. Within the

framework of integration into the EU's unified socio-economic space, human potential acts as an integrative resource capable of ensuring Ukraine's competitive participation in the international division of labour, expanding export opportunities, and increasing the technological level of the national economy. All this determines a shift in traditional views on human potential, which, under modern challenges and radical changes, should be considered as a comprehensive characteristic of the demographic, educational, professional, social, and innovative capacities of the population capable of ensuring structural modernisation of the economy and the formation of sustainable competitive advantages. Its formation and development require a systematic state policy aimed at restoring the demographic base, investing in education and healthcare, stimulating productive employment, and developing human capital in the context of digitalisation and green transformations. It is in this context that human potential becomes a decisive factor in long-term economic sustainability, social stability, and the successful European integration of Ukraine.

Human potential is a complex, multifaceted, and multilevel category, the quantitative and qualitative parameters of which are manifested through its logical connection with labour potential and human capital. Thus, the quantitative and structural basis of human capital is labour potential. Through further qualitative and value transformations, labour potential acquires the socio-economic form of human capital. In the long term, human capital acquires integral characteristics of development and ensures the strategic competitiveness of the national economy (across sectors, industries, territories, etc.), transforming into human potential (Fig. 1).

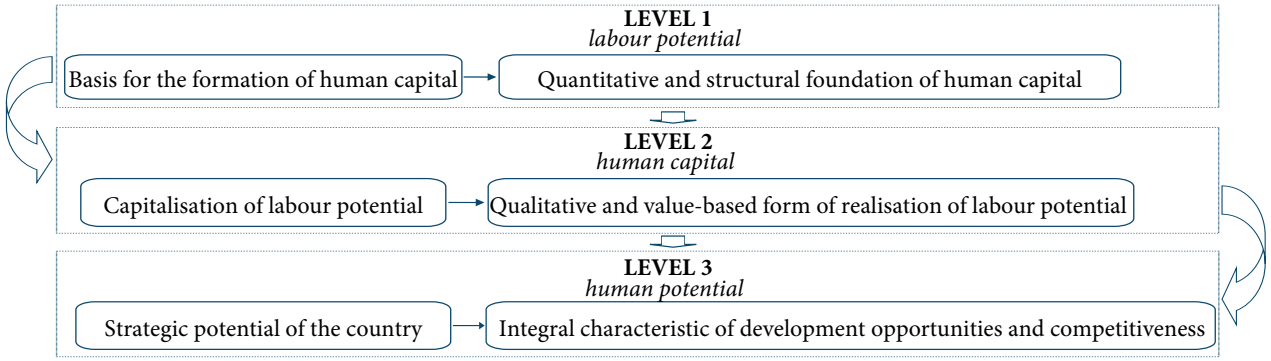

Figure 1. Integral model of human potential formation of the country
Source: developed by the authors

Ensuring equal opportunities for all regions is a critical task for sustainable economic and social progress of society. Despite the difficult socio-economic conditions and geopolitical challenges, the dynamics of the Inclusive Development Index in Ukraine is positive – the country is improving its ranking positions in the international list. Thus, in 2021-2023, the country's rating increased by 24 positions (among 129 countries) with a simultaneous increase in the corresponding IDI coefficient from 53.75 to 58.67 (Fig. 2). The United Nations Development Programme (2025) indicates that Ukraine retains significant human potential, supported by a comparatively high level of educational attainment (11.1 average years of schooling) and a life expectancy of 73.4 years, which constitute important prerequisites for long-term socio-economic development.

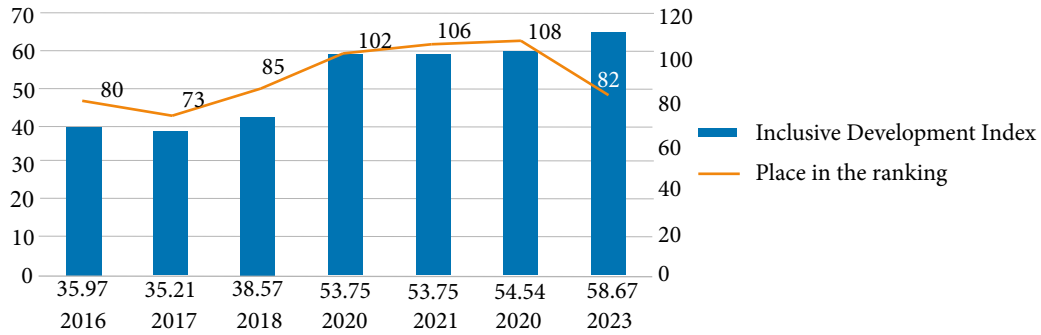

Figure 2. Dynamics of the human development index of Ukraine
Source: compiled by the author based on StatBase (2025)

A qualitative characteristic of human potential under modern conditions is the degree of full realisation of economic, educational, and social opportunities for both women and men. Gender equality and inclusiveness

determine the scale of the utilisation of a country's human capital. Ensuring equal access to education, employment, managerial positions, financial resources, and social protection for all gender groups expands the base of human potential, increases the level of economic activity, and contributes to the formation of a more inclusive and competitive model of national development. From this perspective, gender equality acts not only as a social value but also as an economic prerequisite for improving the quality of human capital and strengthening the country's competitive position in the global arena. In Ukraine, progress in gender equality has been observed in recent years; however, its position in European rankings remains relatively low: in 2023, the Gender Equality Index amounted to 61.4 points, which was 8.8 points lower than the EU average (Ukrainian Women's Fund, 2025).

An essential prerequisite for realising the potential of longevity and human capital is the increase in both the volume and the share of expenditures on healthcare, as well as improving access to high-quality and inclusive medical services for Ukrainians. Research findings indicate that healthcare expenditures in Ukraine were characterised by a steady increase in total volume, reaching UAH 238.6 billion in 2024 (Table 1). At the same time, the share of healthcare expenditures in the structure of consolidated government spending has shown a clear downward trend after 2021: from 11.0% to 4.8% in 2024. On a per capita basis, the average annual government expenditure on healthcare services amounts to UAH 7,167. Analytical data indicate the existence and growth of a significant gap between the level of healthcare financing in Ukraine and EU countries: as of 2023, it amounted to approximately EUR 3,666 per person per year. The growth rates of healthcare spending in Ukraine are also significantly lower compared to European countries.

Table 1. Dynamics of healthcare expenditures in Ukraine and the EU

Year	Healthcare expenditures, billion UAH	Growth rate, %	Share in total government expenditures, %	Expenditures per capita in Ukraine, UAH	Healthcare expenditures per capita in EU countries, EUR	Growth rate of healthcare expenditures, %
2014	57.1	112.6	10.9	1,332.2	2,662.2	101.8
2015	71.0	124.2	10.4	1,658.9	2,742.2	103.2
2016	75.4	106.2	9.0	1,770.2	2,812.7	106.1
2017	102.4	135.8	9.7	2,414.9	2,907.4	103.5
2018	115.8	113.1	9.3	2,751.7	2,999.3	103.4
2019	128.4	110.8	9.4	3,063.9	3,119.1	104.1
2020	175.8	136.9	11.0	4,225.8	3,277.3	105.0
2021	203.6	115.8	11.0	4,942.0	3,570.4	108.8
2022	215.3	105.7	7.1	6,239.9	3,685.4	103.6
2023	217.4	100.9	4.9	6,394.7	3,822.1	103.7
2024	238.6	109.8	4.8	7,166.7	-	-

Source: calculated by the authors based on data from Ministry of Finance of Ukraine (n.d.), Eurostat (n.d.)

In studying the nature of development and assessing human potential, scholars come to a common conclusion that the system-forming factor of its formation and growth is investment in science and education. Investments serve as a source of capitalisation of the country's labour potential and as a driver of its qualitative transformation into human capital. The synergy of educational and scientific components creates conditions for the qualitative reproduction of human capital, enhancement of its intellectual component, and the formation of the country's innovation potential (Kremen *et al.*, 2020). For Ukraine, in the context of structural transformations and European integration, the development of science and education is not only a social priority but also a strategic mechanism for increasing human potential capable of ensuring long-term sustainability and competitive advantages of the national economy.

Recognising the exceptional importance of human capital capitalisation, Ukrainian scholars note (Romaniv, 2025) that the current state of research and development (R&D) in the country is characterised by a systemic insufficiency of resource and financial support. The chronically low share of R&D expenditures in GDP, their instability, and the predominance of public funding under conditions of limited business participation create structural imbalances in the development of the scientific sphere. Under such conditions, scientific activity does not provide an adequate material and technological base for realising the intellectual potential of researchers, which reduces the returns on investments in education and professional training, intensifies migration tendencies among highly qualified personnel, and leads to the loss of intellectual resources. The fragmentation of institutional support for innovation, the insufficient level of integration between science, education, and business, and the limited opportunities for the commercialisation of research results reduce the economic efficiency of scientific developments and prevent the transformation of knowledge into added value (Yurchyshena, 2024).

In the context of military and socio-economic challenges, the risk of preserving a raw-material-based development model increases, which complicates the transition to a knowledge economy. This is confirmed by the traditionally low share of R&D expenditures in Ukraine's GDP, which has decreased over the past ten years from

0.60% to 0.37%, compared to the EU average of 2.24% spent on science (Table 2). As a result, the gap in the level of financial support for the development of the scientific sector between Ukraine and the EU continues to grow and amounts to 1.87%. In per capita terms, expenditures on research and development and the capitalisation of human capital amount to: in Ukraine – UAH 850 (approximately EUR 20), in EU countries – EUR 897. The existence and magnitude of these gaps in financial support for research and development contribute to the widening lag in the innovative development of the national economy and create significant risks of losing its strategic competitive potential.

Table 2. Dynamics of expenditures on education and science in Ukraine and the EU

Years	R&D expenditure, billion UAH	R&D expenditure as % of GDP in Ukraine	R&D expenditure per capita, UAH	Education expenditure, billion UAH	Share of education expenditure in government spending, %	R&D expenditure as % of GDP in EU countries	R&D expenditure per capita, EUR	Gap in R&D funding level, % of GDP
2014	9.5	0.60	221.4	100.1	19.14	2.12	265.9	-1.52
2015	11.0	0.55	257.0	114.2	16.80	2.12	584.2	-1.57
2016	11.5	0.48	270.0	129.4	15.49	2.12	598.4	-1.64
2017	13.4	0.45	316.0	177.7	16.82	2.15	632.9	-1.7
2018	16.8	0.47	399.0	210.0	16.80	2.19	663.7	-1.72
2019	17.3	0.43	412.9	238.7	17.4	2.22	698.5	-1.79
2020	17.0	0.41	408.7	255.3	15.81	2.30	692.2	-1.89
2021	20.9	0.38	507.3	312.9	16.97	2.26	742.4	-1.88
2022	17.1	0.33	495.7	290.7	9.55	2.24	805.7	-1.91
2023	21.3	0.32	626.5	308.6	6.95	2.26	869.3	-1.94
2024	28.3	0.37	849.8	348.4	7.05	2.24	897.2	-1.87

Source: calculated by the authors based on State Statistics Service of Ukraine (n.d.), Ministry of Finance of Ukraine (n.d.), Eurostat (n.d.)

The shift in state funding priorities as a result of the prolonged military conflict exacerbates these risks and increases existing gaps. Overall, the reduction in funding volumes has led to a decline in Ukraine's position in global innovation rankings (Fig. 3). In particular, Ukraine experienced the greatest losses during 2021-2024, dropping by 11 positions globally in terms of the Global Innovation Index (GII) – from 49th place in 2021 to 60th place in 2024. In 2025, this downward trend continued, with Ukraine ranking 66th with a GII score of 29.7.

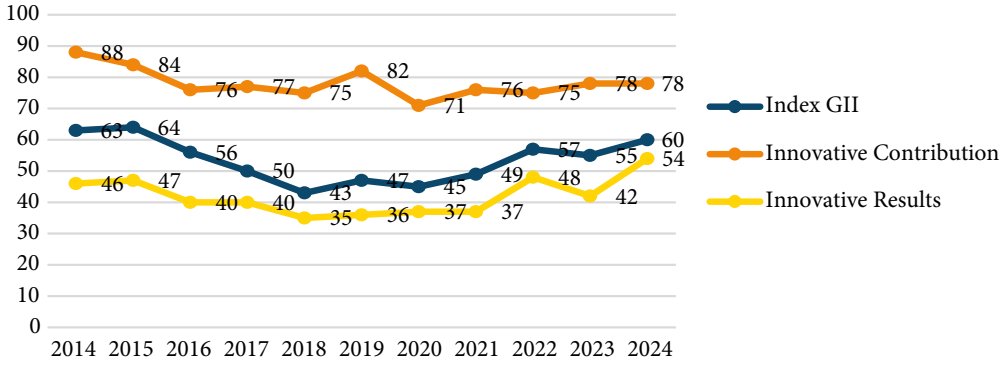

Figure 3. Ukraine's ranking positions in the global innovation environment

Source: compiled by the authors

In addition to the decline in Ukraine's positions in global economic rankings, the military conflict has created a set of systemic risks for the reproduction and development of human potential. These risks manifest across various spheres of social development and have long-term socio-economic consequences. In the social sphere, processes of forced migration, rising unemployment, and loss of household income have intensified, leading to increased social inequality, demographic imbalances, and a decline in the quality of human capital. The deterioration of housing conditions due to infrastructure destruction and mass population displacement results in the loss of a stable environment necessary for personal development, the formation of professional skills, and social integration. The healthcare system has suffered significant losses, manifested in the physical destruction of medical facilities, overburdened resources, increased demand for rehabilitation and psychological support, as well as a deterioration in general health indicators and life expectancy – key components of human capital. In the field of education and science, the conflict has led to the destruction of educational infrastructure, disruption of learning processes, loss of scientific personnel, and weakening of international academic integration, which reduces the country's innovation

potential. Taken together, these factors create a risk of long-term degradation of the qualitative characteristics of Ukraine's human potential and complicate the formation of a competitive model of national economic development in the post-war period.

As of the end of 2024, sectors that are critical for the formation and development of human capital in Ukraine have suffered significant losses and damage. Among them, the estimated damage to the housing sector exceeded USD 78.7 billion, to the education and research sector – USD 23 billion, and to healthcare – USD 21.1 billion (Table 3). In addition, the total direct and indirect damage to the social protection sector and the provision of adequate living conditions amounted to approximately USD 87.7 billion. To restore the conditions necessary for the formation and capitalisation of human potential, Ukraine will require approximately USD 175 billion in capital investments and funding in the near future.

Table 3. Assessment of risks to the formation and development of human capital in Ukraine as a result of the military conflict

Spheres of human capital formation	Amount of losses, billion USD		
	Damage	Losses	Reconstruction needs
Housing sector	57.6	21.1	83.7
Education and science	13.4	9.6	32.9
Healthcare sector	1.5	19.6	19.4
Social protection sector	0.39	87.3	38.8
Total	72.89	137.6	174.8

Source: compiled by the author based on World Bank (n.d.)

According to expert assessments by the Ukrainian analytical centre K. Symonenko (2024), by 2032 the potential losses of the country's human potential due to the consequences of the military conflict may amount to approximately USD 255 billion. Under an optimistic socio-economic development scenario, these losses are estimated at USD 210 billion, resulting from reduced access of the Ukrainian population to fully inclusive systems of education, healthcare, and social protection. Indirect risks of human potential loss in Ukraine arise from the consequences of macroeconomic instability caused by the military conflict, which manifest through the deepening of imbalances in employment, income, and workforce reproduction. The decline in production volumes and GDP losses lead to reduced labour demand, rising unemployment, and forced underemployment, which in turn results in the loss of professional skills, decreased motivation for upskilling, and intensified labour migration. The prolonged exclusion of part of the population from the formal labour market, along with rising inflation, reduces the level of human capital accumulation and limits its future capitalisation.

An assessment of the domestic labour market and its inherent indicators has shown that its structural instability, the transformational nature of the economy, and the impact of wartime shocks complicate the accurate identification of an equilibrium level of employment as a prerequisite for increasing the country's human capital. Unlike developed economies with relatively stable institutional parameters, in Ukraine the natural rate of unemployment is a variable dependent on the scale of labour migration, the shadow economy, regional disparities, and demographic losses. Based on these economic assumptions, calculations were carried out to determine the range of possible GDP losses, reflecting the scale of underutilisation of the country's labour potential due to the wartime shock. These results emphasise that macroeconomic losses for Ukraine are not only cyclical but also deeply structural in nature, directly affecting the processes of human capital capitalisation and the long-term competitiveness of the national economy. The results of forecast calculations of national GDP losses due to unemployment in Ukraine are presented in Table 4.

Table 4. Risks of GDP loss in Ukraine due to unemployment

Data forecast source	U_t, %	U_1, %	GDP loss, %	GDP loss, billion USD
NBU	10.6	5.0	11.2	25.92
NBU	10.6	8.6	4.0	9.26
IMF	10.2	5.0	10.4	24.07
IMF	10.2	8.6	3.2	7.40

Source: developed by the authors

According to forecast data from the National Bank of Ukraine and the IMF, the unemployment rate for 2026 was assumed at 10.6% and 10.2%, respectively. The actual unemployment rate was determined in accordance with the principles of Okun's law, which demonstrates the inverse relationship between cyclical unemployment and the gap between actual and potential GDP, and establishes the existence of a minimum level recorded in the Ukrainian economy during 2014-2024. A prerequisite for a thorough risk classification is the distribution of risks by probability levels and expected impact (Table 5).

Table 5. Risk assessment matrix by probability of occurrence and impact strength

Probability/Impact	1 – Negligible	2 – Moderate	3 – Significant	4 – High	5 – Critical
5 – Very high	5	10	15	20	25
4 – High	4	8	12	16	20
3 – Medium	3	6	9	12	15
2 – Low	2	4	6	8	10
1 – Very low	1	2	3	4	5

Source: compiled by the authors

Interpretation: 1-4 – low risk; 5-9 – moderate; 10-14 – high; 15-25 – critical. To study the human potential of agro-industrial complex enterprises, it is advisable to assess demographic deficit, mobilisation and security restrictions, migration, digital skills deficit, risk of losing qualified employees, territorial mobility and lack of investment in personnel development. Such a matrix allows not only to rank risks, but also to link them to the priority of management measures. Forecast calculations of nominal GDP losses in Ukraine for 2026 indicate that, depending on different assumptions regarding the natural rate of unemployment, the national economy may lose between USD 7 billion and more than USD 25 billion in potential output. Such losses extend beyond short-term macroeconomic effects and generate substantial long-term risks for the formation and reproduction of the country's human potential. In particular, declining economic output weakens the government's fiscal capacity to finance education, scientific research, healthcare, and social protection, thereby limiting investment in the key components of human capital. At the same time, persistently high unemployment contributes to the depreciation of professional skills, reduces labour motivation, and weakens the workforce's ability to adapt to technological and structural changes. Lower employment levels also reduce tax revenues and increase the likelihood of informal economic activity through the concealment of labour income and mandatory social contributions, which further undermines the financial sustainability of the public sector. Furthermore, declining household incomes caused by unemployment constrain private investment in education, health, and professional development, creating a negative intergenerational trajectory in which the quality of human potential gradually deteriorates, reducing the capacity of future generations to contribute to sustainable economic growth.

In the context of Ukraine's post-war recovery, stabilisation of the labour market and reduction of excessive unemployment are key prerequisites for restoring the resource base of the economy and ensuring sustainable growth of human potential. The agri-food sector is one of the fundamental pillars of Ukraine's economic development, national security, and public welfare. This sector accounts for approximately 3.9% of all active business entities, generates 20.6% of the total value of produced output, and contributes 13.3% of the gross value added in the country's overall production. According to economic and statistical observations, 10.4% (7.5 million people) of all employed individuals across economic activities work in the agri-food sector, while the share of hired employees amounts to 11.4% (5.8 million people). Despite the challenges and threats of the political and business environment in recent years, the agri-food sector demonstrated a high level of operational stability. The share of profitable agro-industrial enterprises averages 78% and has remained almost unchanged during the years of war in Ukraine (Table 6). Profitability indicators are also relatively high: in 2024, the overall profitability of agricultural enterprises reached 22.7%, while enterprises producing food, beverages, and tobacco products achieved 7.0%, compared to 5.7% across the national economy as a whole.

Table 6. The role and place of the agri-food sector in the formation of the country's human potential

Years	Number of employed personnel, thousand persons	Share of employed in total structure, %	Number of hired personnel, thousand persons	Share of hired personnel in total structure, %	Share of worked man-hours in the sector, %	Net profit, million UAH	Share of profitable enterprises, %	Share of loss-making enterprises, %
2014	9,008.3	5.1	7,311.6	13.0	15.1	4,575.4	72.9	27.1
2015	8,331.9	11.9	6,589.5	12.9	14.8	86,295.4	80.2	19.8
2016	8,244.0	12.2	6,597.6	13.0	14.8	83,103.6	79.3	20.7
2017	8,271.3	12.0	6,706.2	12.8	14.3	77,754.8	77.7	22.3
2018	8,661.3	11.5	7,088.7	12.0	13.6	86,539.7	78.1	21.9
2019	9,145.5	10.7	7,418.8	11.4	12.7	118,097.4	77.1	22.9
2020	9,057.0	10.4	7,379.5	11.0	12.7	86,867.9	75.7	24.3
2021	9,056.1	10.3	7,368.7	10.9	12.4	260,675.8	78.1	21.9
2022	7,606.0	10.5	6,088.1	11.0	13.5	85,311.7	72.8	27.2
2023	7,514.3	10.1	5,827.1	10.9	13.1	100,714.5	75.0	25.0
2024	7,532.8	10.4	5,809.6	11.4	13.3	205,963.5	78.0	22.0

Source: calculated by the author based on data from the State Statistics Service of Ukraine (n.d.)

Problematic aspects of the formation and development of human potential in the agri-food sector include the need to intensify and increase the level of innovation activity. During 2020-2024, the share of innovation-active enterprises in the sector remained relatively stable and did not exceed 7.8%, while the share of innovation expenditures amounted to 15.6%. The formation and utilisation of human potential in Ukraine's agri-food sector were determined by a combination of structural, institutional, technological, and socio-demographic factors, which define its specificity compared to other sectors of the national economy. The agri-food sector is characterised by a number of specific features that significantly influence the formation and utilisation of human potential. Its development remains highly dependent on natural and climatic conditions, the seasonality of production processes, and the territorial dispersion of production facilities, all of which increase the demand for a flexible and adaptive workforce. At the same time, rapid technological transformation is reshaping the nature of agricultural labour by integrating traditional farming practices with advanced digital technologies, precision agriculture, automation, and artificial intelligence.

The transition toward sustainable development and green production models further increases the need for substantial investment in environmentally friendly technologies, resource-efficient production systems, and the development of new workforce competencies. In addition, the export-oriented nature of Ukraine's agri-food sector makes its competitiveness highly sensitive to fluctuations in global markets, international quality standards, and geopolitical risks. In this context, the literature consistently recognises human capital as a strategic determinant of sustainable agri-food development, as it enhances the sector's capacity to ensure food security, withstand economic and social crises, and adapt to structural, demographic, and institutional transformations (Oviechkina *et al.*, 2021; Lopatynskyi & Palamariuk, 2023; Svynous *et al.*, 2025). Under these conditions, the human potential of the agri-food sector acquires not only an economic but also a spatial and organisational dimension, becoming a strategic factor of long-term competitiveness and post-war economic recovery in Ukraine. According to the author's methodological approach, the most appropriate model under modern conditions is a comprehensive evaluation framework that reflects a sequential transition from labour potential (as a resource base) to human capital (as an economic form of its reproduction), and ultimately to the human potential of the agri-food sector as a result-oriented category manifested in the ability to generate added value and improve final financial outcomes. According to this methodology, the architectural composition of the model for evaluating human potential in the agri-food sector is presented as follows (Fig. 4).

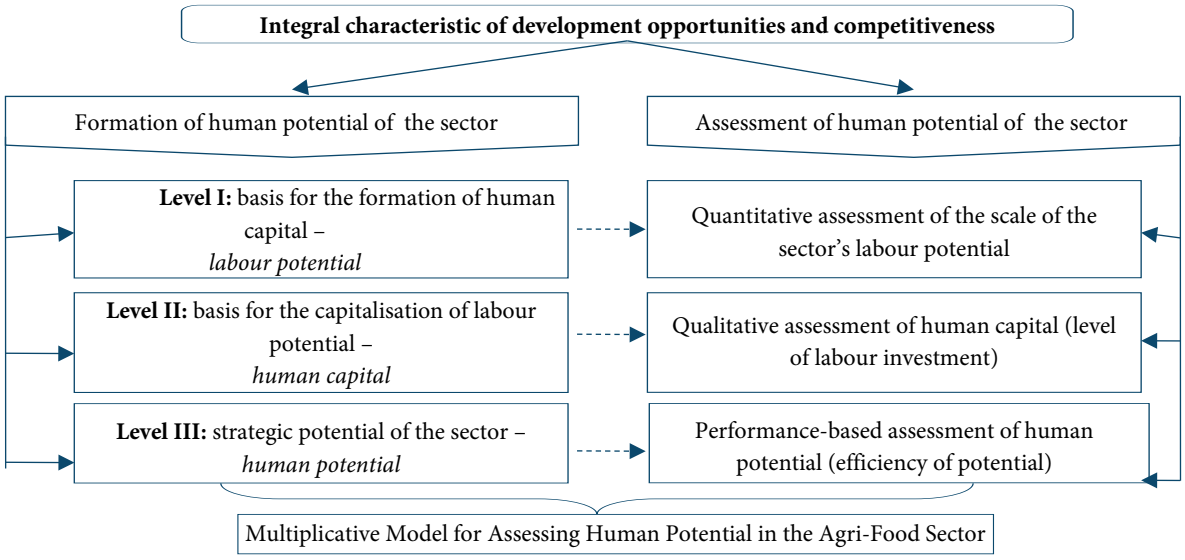

Figure 4. Architecture of the model for assessing human potential in the agri-food sector
Source: developed by the authors

According to the authors, the proposed model is suitable under the current realities of the development of Ukraine's agri-food sector. It allows for the simultaneous consideration of sectoral structural constraints, the need to compensate for labour shortages through investments and technologies, as well as the main final performance criterion – the ability to generate added value and ensure profitability of economic activity. The model integrates quantitative, investment, and performance dimensions into a unified system of evaluation indicators, which are crucial for determining managerial priorities for the further development of human potential and the agri-food sector under wartime conditions and during post-war economic recovery. Positive trends are also observed in the processes of capitalisation of human potential in the agri-food sector: the annual amount of investment per employee has increased to UAH 129.8 thousand, alongside an increase in total expenditures per employee to UAH 230.1 thousand.

Negative trends, however, characterise the performance component of human capital utilisation, reflecting the consequences of macroeconomic instability and wartime crisis shocks (Table 7). During the period 2021-2024, in agri-food sector enterprises, the payback coefficient of personnel costs decreased from 13.3 to 11.5, while operating income per employee declined by 22.2% – from UAH 624.7 thousand to UAH 485.9 thousand. As a result, indicators of value added and net profit per employee also decreased – by 8.7% (to UAH 703.9 thousand) and 6.1% (to UAH 261.7 thousand), respectively. However, during the period 2022-2024, business entities in the agri-food sector managed to halt the negative trend of declining profitability and demonstrated relatively high profitability levels (14.9%) compared to the average across all types of economic activity (7.0%).

Table 7. Quantitative assessment of human potential in the agri-food sector of Ukraine

Indicators	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2024 vs 2021	
												(+,-)	%
Indicators of concentration (scale) of human potential													
Average number of employees per enterprise. persons	5.0	10.4	11.2	10.9	10.8	10.6	10.5	10.7	11.8	9.6	10.4	-0.4	96.7
Share of hired employees in total employment, %	85.4	85.4	85.4	85.9	85.9	86.5	86.3	85.8	83.8	83.5	83.8	-2.0	x
Indicators of investment in human potential (quality of human potential)													
Annual personnel costs per hired employee, thousand UAH	48.2	59.5	66.3	88.9	111.6	131.1	145.0	170.6	193.0	230.1	260.1	89.5	152.5
Share of personnel costs in total cost structure. %	20.7	17.1	16.4	18.3	19.1	21.4	21.6	21.5	21.1	20	21.2	-0.3	x
Investment per employed person, thousand UAH	70.3	44.4	68.8	83.8	98.1	93.0	84.6	104.9	86.5	129.8	103.9	-1.0	99.1
Indicators of human potential utilisation													
Return on personnel costs, UAH	12.9	15.7	16.1	14.6	13.0	11.5	11.9	13.3	11.2	11.5	11.3	-2.1	84.6
Gross operating income per employee, thousand UAH	373.9	235.3	237.4	260.0	238.6	244.4	329.6	624.7	395.3	414.7	485.9	-138.8	77.8
Gross value added per employee, thousand UAH	469.7	284.1	293.0	336.4	334.5	357.7	454.8	771.1	557.2	606.8	703.9	-67.2	91.3
Net profit per employee, thousand UAH	10.0	86.7	82.6	78.1	87.2	121.1	92.2	278.8	107.2	132.6	261.7	-17.1	93.9
Overall profitability level, %	12.9	22.4	17.6	13.8	11.6	12.2	12.0	22.2	13.9	10.3	14.9	-7.3	x

Source: calculated by the author based on State Statistics Service of Ukraine (n.d.)

Taking into account the need to consider all factors influencing the formation and utilisation of human potential, as well as the changes caused by the consequences of the military conflict, a model for assessing the human potential of the agri-food sector should be developed, which must be multiplicative in nature. The results of the SWOT analysis of the human potential of Ukraine's agri-food sector (Table 8) indicated that the sector is developing according to an investment-adaptive model: its human potential is capable of generating high added value; despite macroeconomic instability, there is an increase in the sector's human capital (through growing investment volumes and created added value); and the agri-food sector maintains functional resilience and stability under crisis conditions.

Table 8. SWOT analysis matrix of human potential development in the agri-food sector of Ukraine

Strengths (S)	Weaknesses (W)
High labour productivity and potential for value creation; availability of investment resources for modernisation; experienced workforce; high adaptability of the sector to crises; gradual transition to a more technology-driven production model; significant role of the sector in the national economy and security	Inertia in the implementation of investments in human capital; declining short-term return on personnel costs; aging workforce and demographic decline in rural areas; shortage of certain categories of qualified specialists (agro-engineering, agri-IT, management); uneven level of workforce training across regions; high dependence on external markets
Opportunities (O)	**Threats (T)**
Deepening integration with the EU; growing demand for environmentally friendly food products in EU markets; digitalisation of agricultural production and the food industry; development of agricultural education and dual training; increasing added value through food processing; ESG transformation and "green" development; growth and dissemination of agri-tech startups	Military risks and infrastructure destruction; migration of the working-age population; reduction in labour resources in the sector; instability of logistics and sales markets; rising cost of resources and energy dependence; strong competition from transnational agricultural holdings

Source: compiled by the authors

The main challenge for the formation, utilisation, and development of human potential in the sector is structural asymmetry and the time lag between investments and their short-term returns, which creates financial pressure and the risk of underestimating human potential. The human potential of Ukraine's agri-food sector is characterised by a strong productive and adaptive capacity; however, its development under current conditions is constrained by demographic and institutional limitations of the national economy. In the current crisis conditions, the formation, use and development of human potential in the agri-food sector of Ukraine is accompanied by a complex of interrelated risks of a demographic, security, socio-economic, organisational and technological nature. In the area of human potential formation, one of the most systemic challenges is the demographic "narrowing" of the labour base and the reduction of the working-age population, which creates a long-term labour shortage. Additionally, mobilisation processes and security restrictions exacerbate the structural shortage of personnel, reducing the availability of qualified workers for agri-food production. At the same time, the destruction or insufficient availability of social, educational, medical and transport infrastructure in rural areas worsens the conditions for the reproduction of labour potential and reduces the attractiveness of rural areas for residence and employment.

In the process of using human potential, significant risks remain seasonality and territorial dispersion of employment, which complicate the provision of stable employment and reduce the predictability of labour productivity, which in parallel deepens the mismatch between the existing competencies of workers and the technological needs of modern agri-food production, especially as a result of the spread of automation, digital platforms, precision agriculture, robotisation and data analytics. A separate threat is the outpacing growth of personnel costs without a proportional increase in labour productivity, which in the short term may worsen the financial results of enterprises. Military risks additionally disrupt production and logistics cycles, complicate the movement of workers and access to jobs, and destabilise value chains in the agri-food sector. The development of human potential, in turn, is limited by the risk of investment inertia in professional training and staff development, since the economic effect of such investments is usually delayed. In conditions of political and macroeconomic instability, enterprises may reduce or postpone investments in human capital, giving priority to the current provision of operational activities. Such a strategy allows to reduce the short-term financial burden, but at the same time increases the risk of technological and competence lag, weakens the adaptability of personnel and in the long term may reduce the competitiveness of agri-food enterprises.

Additional risks to the formation and development of human potential in Ukraine's agri-food sector are associated with the objective need to transition to a sustainable production model, which includes reducing resource intensity, decarbonisation, soil and biodiversity conservation, the development of circular practices, and increased transparency in corporate governance in line with ESG principles, therefore, the formation of effective local development models based on the diversification of economic activity, support for cooperation, development of innovations, circular economy, and strengthening the institutional capacity of territorial communities is of particular importance. In the short term, these risks imply a significant increase in costs for modernisation, greening of production, and workforce training, which, under wartime economic conditions and limited access to financial resources, creates additional burdens and uncertainties for Ukrainian businesses.

Discussion

The theoretical basis of the concept of human capital, developed by T. Schultz (1961) and G. Becker (1975), is based on the recognition of a person as the main productive resource of the economy, and investments in education, vocational training, health and development of competencies as a key source of economic growth, increased labour productivity and social welfare. T. Schultz proved the crucial role of knowledge and skills in the formation of national wealth, while G. Becker substantiated the economic efficiency of investments in human capital and their impact on income, employment and competitiveness. The synergy of the digital economy and human capital (Vasyltsiv *et al*., 2024) confirms the conceptual position that the transformation of human potential in is one of the key mechanisms of the post-war economic recovery of Ukraine. It was established that its impact on socio-economic development is determined not only by demographic characteristics, but also by the level of digitalisation, institutional quality, infrastructure development and general macroeconomic conditions that determine its value as a strategic innovation resource. The transition to significant effects from the advantages of cooperation and circular practices can be realised only if the systemic relationships between human capital, technological changes and the institutional environment are taken into account. This was confirmed by modern theoretical approaches reflected in studies by M. Henrysson & R. Laurenti *et al*. (2018), C. Nuur (2021) and E. Arthur *et al*. (2023), which prove that the benefits of cooperation, digitalisation and circular practices are realised only under the condition of interaction of human capital, technological innovations and an effective institutional environment that forms the systemic prerequisites for sustainable development and economic sustainability. The effectiveness of innovative transformations depends not so much on individual technologies as on the quality of governance, social capital and the ability of the economic system to adapt. A particularly important component is the heterogeneity of the impact of individual components, among which the most stable drivers of social progress were infrastructure and human capital, the role of which is enhanced when time lags are taken into account by M. Azimi *et al*. (2025) and M. Gariba *et al*. (2026). This suggests that long-term

competitiveness is primarily shaped by the accumulation of basic production and intellectual capabilities, while the effect of individual digital services is more dependent on global trends in technological diffusion.

The findings confirmed that the deterioration of human potential in Ukraine is driven by the cumulative effects of demographic decline, labour migration, reduced public investment in healthcare and education, labour market instability, and the destructive consequences of the military conflict. Unlike studies that examine these factors separately, the present research demonstrated their systemic interaction and showed that their combined influence significantly constrains the country's long-term socio-economic resilience and post-war recovery. The obtained results are consistent with the conceptual framework of human development proposed by the United Nations Development Programme, according to which sustainable economic growth depends on simultaneous progress in health, education, and living standards. The observed decline in Ukraine's human development indicators during the war confirms that armed conflict undermines not only current economic performance but also the capacity for long-term human capital reproduction. The comparative analysis of healthcare, education, and research expenditures revealed a persistent investment gap between Ukraine and the European Union. These findings support previous studies arguing that insufficient public investment weakens labour productivity, innovation capacity, and economic competitiveness. At the same time, the results indicate that the consequences of war substantially amplify these structural weaknesses, creating additional barriers to human capital accumulation and increasing regional disparities.

The scenario analysis based on Okun's law demonstrated that rising unemployment may generate substantial macroeconomic losses through reduced economic output. While the relationship between unemployment and GDP has been widely documented in the literature, the present study extends its application to wartime conditions by illustrating the potential economic consequences of prolonged labour market deterioration in Ukraine. The scenario calculations provide quantitative evidence that employment recovery should be considered one of the central priorities of post-war economic policy. The assessment of risks to human potential further demonstrates that demographic losses, forced migration, educational disruption, and healthcare constraints represent interconnected rather than isolated challenges. This finding supports previous research emphasising that post-conflict recovery requires integrated public policies combining labour market measures, educational reforms, healthcare investment, and demographic support. The proposed conceptual model contributes to this discussion by integrating these dimensions into a unified framework for assessing human potential.

The analysis of the agri-food sector confirms its strategic role in maintaining employment, generating income, and supporting regional socio-economic stability during wartime. The calculated corporate performance indicators show that the efficiency of human capital utilisation varies considerably over time, reflecting both macroeconomic shocks and structural changes within the sector. These findings suggest that improving labour productivity and increasing the return on human capital investments remain essential conditions for strengthening the resilience and competitiveness of the agri-food economy. The integrated assessment model proposed in this study extends previous approaches by combining demographic, educational, healthcare, labour-market, innovation, and economic indicators into a comprehensive analytical framework. Unlike traditional assessments based on individual indicators, the proposed approach captures the multidimensional nature of human potential and enables a more comprehensive evaluation of the factors determining its formation and reproduction under conditions of military conflict.

The SWOT analysis complements the quantitative findings by demonstrating that Ukraine possesses significant endogenous strengths, particularly its agricultural potential, educational capacity, and opportunities for European integration. However, these advantages are offset by demographic decline, migration losses, labour shortages, and institutional constraints. Consequently, post-war recovery policies should prioritise investment in education, healthcare, productive employment, and regional development while strengthening institutional capacity and aligning national policies with European standards. The study has several limitations. First, the analysis relies primarily on official national and international statistical data, which may be revised as new information on wartime losses becomes available. Second, the scenario estimates based on Okun's law provide analytical projections rather than forecasts of actual GDP dynamics. Third, the integrated assessment model focuses on macroeconomic and sectoral indicators and does not include enterprise-level or household-level microdata. These limitations, however, do not affect the overall validity of the identified relationships and conclusions. Overall, the results demonstrate that sustainable post-war recovery requires a comprehensive approach to human potential development, combining investment in human capital, labour market revitalisation, institutional reforms, and support for strategically important sectors such as the agri-food industry. The proposed methodological framework may serve as a basis for future empirical studies evaluating the effectiveness of recovery policies and human capital development strategies in Ukraine.

There is a certain gap between the pace of implementation of digital innovations and the speed of adaptation of human capital to new requirements. In the context of the knowledge economy, digital technologies significantly lower barriers to access to the labour market, opening up new opportunities for remote employment, entrepreneurship, self-employment and participation in global value chains. Thanks to this, a person receives a wider choice of trajectories of professional self-realisation, and society – the opportunity to use the accumulated human capital more effectively. Digitalisation acquires particular importance in

conditions of demographic aging and labour shortage, as it allows for continued economic activity, support professional mobility and ensure the transfer of knowledge between generations. In this sense, digital technologies act not only as a factor of economic growth, but also as a mechanism for capitalising knowledge, experience and creative potential of a person, contributing to the maximum realisation of their capabilities throughout life.

Digital technologies transform human capital from a resource limited by time and space into a dynamic asset capable of constantly updating, scaling and generating new value. They create conditions for transforming human knowledge, competencies and life experience into a source of long-term economic and social productivity, which makes digitalisation one of the key factors in the realisation of human potential in the economy of the future. The method of predictive modelling was used by V. Demydenko (2026) to assess the long-term consequences of current decisions of public authorities (in particular, regarding the migration of young people aged 18-22) identified points of "no return" of human capital. Concepts such as "active longevity" (Prodanova & Lutay, 2026) and the "silver economy", while beyond the scope of the indicators analysed in this study, are relevant to the extent that they cannot, on their own, compensate for the fundamental demographic losses identified in Results. Even if the economic activity of older age groups continues successfully, such measures will only partially alleviate the labour shortage, but will not ensure population reproduction and long-term stability of the demographic structure. The key threat to the human potential of Ukraine remains the narrowing of the youth and reproductive base of the population. Of particular concern is the outflow of young people aged 18-22, who are the carriers of the greatest educational, innovative and reproductive potential. It is this age group that forms the future highly qualified labour resource, the entrepreneurial layer and the basis of the birth rate of the coming decades. The loss of a significant part of young people through educational and labour migration creates the risk of irreversible population decline and the destruction of mechanisms for intergenerational reproduction of human capital.

From an economic point of view, investments in active longevity are characterised by a longer payback period and a lower potential for accumulation of human capital compared to investments in youth. Expenditures on professional retraining of employees of older age groups, adaptation of workplaces, medical support and maintenance of working capacity should be carried out in conditions of a shortened horizon of labour activity. At the same time, investments in the younger generation provide a longer period of economic return, higher mobility, adaptability to technological changes, and greater potential for family formation and childbearing. An additional limitation is the relatively low average life expectancy in Ukraine compared to most EU countries. In countries where the concept of a "silver economy" has become an important driver of development, it is implemented in conditions of high healthy life expectancy, stable pension systems, and significantly better health indicators of the population. In Ukraine, the primary task remains not only to extend life expectancy, but also to preserve the population size and restore the country's demographic potential.

Therefore, in the system of priorities for post-war development of Ukraine, the policy of active longevity should be considered as an auxiliary tool for mitigating the shortage of labour resources, while the strategic emphasis should be shifted to preserving youth in the country, stimulating the birth rate, returning migrants, attracting young professionals to economic activity, and creating conditions for the expanded reproduction of human potential. It is these areas that will determine the possibility of restoring the demographic base and ensuring the long-term economic security of the state.

The cooperative form of management eliminates the risks of innovative passivity of small farmers. Cooperatives act as centres of knowledge transfer, reducing transaction costs for training and adapting employees to the requirements of sustainable development. Unlike infrastructure, human capital demonstrates a threshold effect. This means that digital skills, innovation culture and professional competencies begin to significantly affect economic outcomes only after reaching a certain critical level of development. This effect confirms the provisions of the human capital theory and the concept of digital readiness, according to which technology technologies do not create added value in themselves without the availability of trained personnel capable of integrating them into production and management processes. For Ukraine, this means that the post-war recovery strategy should focus not only on the physical reconstruction of infrastructure, but primarily on the development of the educational, scientific and professional potential of the population. S. Poghosyan *et al.* (2026) substantiated the methodology of synergistic combination of artificial intelligence and human intelligence. These findings are consistent with the general logic of the present study: in the agri-food sector, returns on investment in human capital materialise only once workers reach a threshold level of digital and professional competence. This suggests that, alongside the cooperative and investment mechanisms examined here, the sector's longer-term capacity to absorb technologies such as circular production models or AI-assisted management remains an important direction for future research, beyond what the present data can support. The results of the study prove that the effectiveness of digital transformations is maximised only when technologies are integrated into management processes as cognitive assistants, which requires the development of a human-centric conceptual model for the retraining of human capital and the integration of technologies in the era of artificial intelligence.

The formation and use of human potential in the agri-food sector of Ukraine under current realities acquire a multidimensional character – the sector operates based on principles of economic resilience and adaptation to

structural shocks caused by military risks, demographic losses, migration processes, and changes in external economic conditions. Under such circumstances, the assessment of human potential requires adjustments to existing evaluation models, which can no longer be limited to traditional indicators such as the number of employed persons, wage levels, personnel costs, etc. Quantitative parameters of labour resources increasingly act as constraints on development, while the key task becomes improving the quality of labour and the efficiency of its utilisation through technological enhancement and capitalisation of labour resources.

Cooperation in modern conditions acts not only as an economic model, but also as a social institution of inclusive development, ensuring access of small producers to resources, technologies, logistics and markets and should be supported by all means and introduced in frontline areas. For small farmers and households, cooperative forms of management create an "effect of scale", allowing them to join modern technologies and grants, integrate into value chains and reduce the digital and economic gap between the city and the countryside. At the same time, cooperatives form an environment for the economic self-realisation of youth and women without the need for labour migration, contributing to the strengthening of social cohesion of rural communities. The combination of human development policies, economic inclusion and spatial sustainability should become the basis for the post-war reconstruction of rural areas of Ukraine. The consolidation of youth through support for family entrepreneurship, farming, cooperative business models, the development of digital infrastructure, housing, education and modern services is of key importance. In the context of demographic losses, declining birth rates, and large-scale migration, it is the young population that will determine the potential for long-term reproduction of human capital and the economic sustainability of the state. On the basis of sustainability, cooperatives become an effective platform for the implementation of green technologies and circular business models. Energy cooperatives, the joint use of biogas plants, solar energy, and agricultural waste processing contribute to resource conservation, energy independence of communities, and the implementation of the principles of the circular economy. At the same time, the digitalisation of cooperative activities, in particular the use of cooperative platforms and data management systems, increases the transparency, adaptability, and efficiency of agri-food systems. In the context of post-war recovery, cooperative models can also perform an important social and reintegration function, in particular through the creation of veteran cooperatives as a mechanism for employment and adaptation. In this context, cooperation transforms a rural resident from an object of social support to an active subject of economic development, creating the prerequisites for the transition from a survival model to a model of sustainable prosperity. Under such conditions, the cooperative model in the agri-food sector should be considered as an integrated sustainability management system that combines collective interaction, digital technologies and risk management mechanisms. At the same time, the post-war development strategy of Ukraine cannot be based solely on replacing the labour shortage with external migration, since human capital is not only a labour resource, but a complex of knowledge, social ties, cultural identity and demographic potential, the reproduction of which is critically important for the long-term economic security of the state.

Conclusions

Due to the existing economic, social, and educational crisis in Ukraine, the next generation may not be able to realise the same level of potential as the previous one, leading to societal degradation. It is therefore evident that there is a need to transition to an adaptive, innovation-oriented model of human potential development based on the principles of sustainability, digitalisation, and the circular economy, with a focus on rural-forming cooperative models and the revival of national agro-industrial enterprises as key elements of sustainable development in the agri-food sector. The negative demographic trajectory is a manageable variable rather than a predetermined outcome; however, a transition to a positive scenario is only possible through active demographic policy, economic recovery, and the development of rural-forming cooperative models. This would stimulate the revival of agro-industrial systems as a foundation for employment and population retention in depressed regions of the country.

At the same time, the absence of such transformations generates a strategic risk of losing access to premium segments of EU markets, reducing export margins, and increasing dependence on less demanding but more volatile external markets. The experience of EU countries clearly demonstrated that modernisation of the agri-food sector without parallel workforce upskilling led to incomplete realisation of technological potential, increased operating costs, and reduced investment returns. For Ukraine's agri-food sector, this implies the need to develop an integrated policy combining financial incentives for the adoption of "green" and digital technologies with systematic support for vocational education, dual training programs, advisory services, and knowledge transfer institutions. Only under such conditions will human potential become not a constraint but a driver of European integration processes. The risks of strategic transformational changes require measures aimed at aligning investment, educational, and institutional policies with the long-term goal of forming a competitive, technologically advanced, and environmentally responsible agri-food sector in Ukraine, where human potential plays a central system-forming role. Future research should focus on developing a new paradigm for the agri-food sector, where cooperative models and national agro-industrial enterprises act as key drivers of human potential recovery, economic self-sufficiency, and spatial cohesion of rural territories in Ukraine.

Acknowledgements

None.

Funding
None.

Conflict of Interest
None.

References

[1] Arthur, E.E., Gyamfi, S., Gerstlberger, W., Stejskal, J., & Prokop, V. (2023). Towards circular economy: Unveiling heterogeneous effects of government policy stringency, environmentally related innovation, and human capital within OECD countries. *Sustainability*, 15(6), article number 4959. doi: 10.3390/su15064959.

[2] Azimi, M.N., Rahman, M.M., & Maraseni, T. (2025). From fragility to resilience: Human capital-driven circular economy transition amid economic complexity and institutional challenges. *Sustainable Futures*, 10, article number 101351. doi: 10.1016/j.sftr.2025.101351.

[3] Becker, G.S. (1975). *Human capital: A theoretical and empirical analysis, with special reference to education* (2nd edition). Cambridge: NBER.

[4] Demydenko, V. (2026). Transformation of municipal & legal mechanisms for development of human potential in context of migration challenges and demographic crisis in Ukraine. *Migration & Law*, 6(2), 24-39. doi: 10.32752/2786-5185-2026-6-2-24-39.

[5] Eurostat. (n.d.). *Health care expenditure*. Retrieved from https://ec.europa.eu/eurostat/databrowser/product/page/HLTH_SHA11_HF.

[6] Gariba, M.I., Odei, S.A., Arthur, E.E., & Soukal, I. (2026). Driving circular economy transformation through technological innovation: The moderating role of regulatory environment, human capital, and technological capacity. *Humanities and Social Sciences Communications*, 13, article number 225. doi: 10.1057/s41599-025-06414-2.

[7] Henrysson, M., & Nuur, C. (2021). The role of institutions in creating circular economy pathways for regional development. *The Journal of Environment & Development*, 30(2), 149-171. doi: 10.1177/1070496521991876.

[8] Kolot, A.M. (2025). Socio-labour platform "Work 5.0": The concept of the future that is coming. In *Work in the 21st century: New trends, social dimension, and innovative development: Proceedings of the international scientific and practical conference dedicated to the 60th anniversary of the department of socioeconomics and human resource management* (pp. 8-20). Kyiv: Kyiv National Economic University named after Vadym Hetman.

[9] Kremen, V.H., Lugovyi, V.I., & Saukh, P.Y. (2020). Education and science – the basis of innovative human development. *Herald of the National Academy of Educational Sciences of Ukraine*, 2(2). doi: 10.37472/2707-305X-2020-2-2-14-3.

[10] Laurenti, R., Singh, J., Frostell, B., Sinha, R., & Binder, C.R. (2018). The socio-economic embeddedness of the circular economy: An integrative framework. *Sustainability*, 10(7), article number 2129. doi: 10.3390/su10072129.

[11] Libanova, E.M. (2025). Human capital of Ukraine: Losses due to the war and prospects for post-war revival. *Visnyk of the National Academy of Sciences of Ukraine*, 4, 38-46. doi: 10.15407/visn2025.04.038.

[12] Lopatynskyi, Y., & Palamariuk, T. (2023). Human capital development in agricultural entrepreneurship. *Scientific Journal of Yuriy Fedkovych Chernivtsi National University. Economics*, 2, 74-79. doi: 10.32782/ecovis/2023-2-12.

[13] Ministry of Finance of Ukraine. (n.d.). Retrieved from https://index.minfin.com.ua/ua.

[14] Nazarov, M., & Kurytskyi, V. (2026). State and problems of socio-economic infrastructure in Ukraine's wartime economy. *Economic Space*, 210, 64-70. doi: 10.30838/EP.210.64-70.

[15] Oviechkina, O.A., Maslosh, O.V., & Zhuravlova, A.O. (2021). Human capital of agrosector of domestic economy: Problems of reproduction in aspect of food security. *Visnyk of the Volodymyr Dahl East Ukrainian National University*, 6, 35-40. doi: 10.33216/1998-7927-2021-270-6-35-40.

[16] Poghosyan, S., Poghosyan, M., Nalbandyan, H., Beglaryan, L., Harutyunyan, A., Adonts, N., Azatyan, L., & Asatryan, H. (2026). Reskilling human capital in the AI era: A human-centric conceptual "spider web" model of knowledge and technology integration. *Cogent Arts & Humanities*, 13(1), article number 2617070. doi: 10.1080/23311983.2026.2617070.

[17] Prodanova, L.V., & Lutay, L.A. (2026). Strategies for preserving and reproducing human capital in the context of global population aging. *Achievements of the Economy: Prospects and Innovations*, 27. doi: 10.5281/zenodo.18996183.

[18] Radkevych, D.O. (2025). The state and prospects of human capital development in Ukraine in the context of social inclusion. *Scientific Notes of Lviv University of Business and Law*, 46, 457-466. doi: 10.5281/zenodo.17715659.

[19] Romaniv, R.V. (2025). Features of R&D expenditures in regional models of innovation management. *Economics, Management and Administration*, 3, 12-16. doi: 10.26642/ema-2025-3(113)-12-16.

[20] Schultz, T.W. (1961). Investment in human capital. *The American Economic Review*, 51(1), 1-17.

[21] Shapa, N., Ufimtseva, O., Skrypnyk, N., Zamlynskyi, V., & Reznik, N. (2025). Exploring employee perceptions of organizational changes and approaches to measuring motivation levels. In B. Alareeni (Ed.), *Big data in finance: Transforming the financial landscape* (pp. 397-411). Cham: Springer Nature. doi: 10.1007/978-3-031-75095-3_32.

[22] State Statistics Service of Ukraine. (n.d.) Retrieved from https://stat.gov.ua/uk.

[23] Svynous, I., Prysiazhniuk, N., Fedoruk, Y., & Pavlichenko, A. (2025). Reproduction of human capital of rural areas as a prerequisite for the resilience of the food system. *Innovative Economy*, 4, 23-29. doi: 10.37332/2309-1533.2025.4.3.

[24] Symonenko, K. (2024). *Labour market in Ukraine: Forecasts and prospects from the director of the EasyBusiness analytical centre.* Retrieved from https://surl.lt/etyhzy.

[25] Ukrainian Women's Fund. (2025). *Gender equality index in Ukraine 2025*. Kyiv: Ukrainian Women's Fund.
[26] United Nations Development Programme. (2025). *Human development index and its components*. Retrieved from https://data.un.org/DocumentData.aspx?id=503.
[27] Ushenko, N.V., & Kurochka, O. (2025). Status and dynamics of human capital development: Inter-country comparisons EU and Ukraine. *Time Description of Economic Reforms*, 4, 123-134. doi: 10.32620/cher.2025.4.14.
[28] Vasyltsiv, T., Lupak, R., Mulska, O., Levytska, O., & Baranyak, I. (2024). Youth migration during war: Triggers of positive aspirations and preservation of human resources in Ukraine. *Problems and Perspectives in Management*, 22(2), 627-641. doi: 10.21511/ppm.22(2).2024.49.
[29] World Intellectual Property Organization. (2025). *Global innovation index 2025: Innovation at a crossroads*. Geneva: World Intellectual Property Organization. doi: 10.34667/tind.58864.
[30] Yurchyshena, L. (2024). Expenditures on research and development and Ukraine's ranking in the global innovation index. *Educational Analytics of Ukraine*, 3, 16-28. doi: 10.32987/2617-8532-2024-3-16-28.

Формування людського потенціалу в умовах розвитку кооперaційних екосистем: стратегія сталого відродження економіки

Віктор Федака
Аспірант
Одеський національний технологічний університет
65039, вул. Канатна, 112, м. Одеса, Україна
https://orcid.org/0009-0004-7298-9070

Наталія Скрипник
Кандидат економічних наук
Національний університет «Одеська політехніка»
65044, просп. Шевченка, 1, м. Одеса, Україна
https://orcid.org/0000-0003-1331-2698

Віктор Замлинський
Доктор економічних наук, професор
Одеський національний технологічний університет
65039, вул. Канатна, 112, м. Одеса, Україна
https://orcid.org/0000-0001-7642-2443

Анотація. Актуальність дослідження зумовлена необхідністю збереження та відновлення людського потенціалу України в умовах воєнних викликів, демографічних втрат і трансформації агропродовольчої сфери як стратегічного сектора національної економіки у сталі кооперaційні екосистеми. Особливого значення набуває пошук ефективних механізмів відтворення людського капіталу для забезпечення продовольчої безпеки та сталого розвитку територій. Метою дослідження було обґрунтування теоретико-методичних засад оцінювання людського потенціалу країни з акцентом на агропродовольчу сферу та розвиток кооперaційних екосистем як стратегічного механізму його відтворення в умовах сучасних соціально-економічних трансформацій. Методологічною основою дослідження стали системний, структурно-функціональний, порівняльний та економіко-статистичний підходи, а також SWOT-аналіз, що дозволило комплексно оцінити стан, ризики та перспективи розвитку людського потенціалу. Для формалізації процесів його відтворення використано концептуальне моделювання та метод інтегральної оцінки. Встановлено, що людський потенціал є ключовим чинником економічної стійкості та конкурентоспроможності держави в умовах воєнних і післявоєнних трансформацій. Проаналізовано динаміку індексу людського розвитку України та виявлено негативний вплив демографічних втрат, міграційних процесів і структурних дисбалансів на якісні характеристики людського капіталу. Оцінено рівень фінансування охорони здоров'я та визначено його відставання від європейських стандартів. Досліджено позиції України у глобальному інноваційному середовищі та обґрунтовано їх значення для відтворення інтелектуального капіталу. Систематизовано ризики втрати людського потенціалу внаслідок війни та здійснено оцінку їх впливу на економічний розвиток. Розроблено концептуальну модель оцінювання людського потенціалу агропродовольчої сфери, а також визначено переваги, обмеження, можливості й загрози його розвитку. Практична цінність результатів полягає у можливості їх використання органами державного управління, науковими установами та суб'єктами агропромислового сектору при формуванні стратегій відновлення людського потенціалу, розвитку сільських територій та забезпечення сталого функціонування агропродовольчої системи України

Ключові слова: людський капітал; демографічна трансформація; трудовий потенціал; продовольча безпека; соціально-економічна згуртованість; інституційний розвиток; післявоєнне відновлення