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Sustainable food production and strategic management: An in-depth analysis

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Abstract. The study aimed to conduct an in-depth analysis of the principles of sustainable food production, identify key challenges and develop strategic recommendations for overcoming them in the global and regional contexts of Ukraine. The research methodology was based on a comprehensive interdisciplinary approach combining comparative, analytical and systemic methods for a complete assessment of the environmental, economic and social components of food systems in the context of contemporary global challenges, food sector development trends and the impact of technological transformations. An in-depth analysis of the theoretical foundations of sustainable food production was conducted, state and corporate strategies for food resource management were studied, and international initiatives, cooperation programmes and innovative technological solutions aimed at improving the efficiency and sustainability of agricultural and food systems were examined. The study established that effective strategic management contributes to the deep integration of environmental, social and economic factors into food production systems, ensuring the balanced development of the agricultural sector. A set of recommendations has been developed on adapting international experience to the conditions in Ukraine, particularly in the field of agrotechnology development, improving public administration mechanisms and training highly qualified personnel for the food sector. Successful cases from EU countries, the US and China were analysed, their effective models for implementing sustainable practices were identified, and the possibilities for application of the approaches in the domestic context were determined. At the same time, the study determined that imperfect institutional mechanisms, limited financial resources and insufficient coordination between public and private structures remain key barriers to sustainability. The practical value of the study is determined by the possible use of the results by specialists in the field of strategic management, public policy and agricultural development to improve the effectiveness of national food security programmes and achieve the UN Sustainable Development Goals

Keywords: sustainable development; institutional mechanisms; crisis adaptation; global challenges to the food system; ecological and economic relations; responsible production; innovative development; natural resources

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INTRODUCTION

Food systems are in crisis due to a range of global and local challenges, affecting environmental, economic and social stability. Population growth, climate change, natural resource degradation, biodiversity loss and socio-economic inequality reduce efficiency of traditional agricultural production models. Ukraine is experiencing the effects of temperature increase, droughts and declining soil fertility, which risk food security and agriculture efficiency. Increase in socio-economic differentiation, urbanisation, market instability and geopolitical risks further also increase the vulnerability of food systems by limiting access to resources and technologies. Intensive farming models prioritising maximum yields have depleted ecosystems and increased anthropogenic impacts on the government. Therefore, strategic management for balance of economic efficiency, social equality and environmental responsibility is necessary. There is a need to identify efficient institutional, technological and management mechanisms that can transform existing food systems into sustainable, adaptive and equitable structures that can address complex challenges.

Food systems are under pressure from a multitude of interrelated factors and are undergoing a critical transition caused by profound structural changes. The expected population growth to 9.7 billion by 2050 will require a significant increase in food production. According to M. van Dijk *et al*. (2021), global food production must increase by 50-70% to meet increased demand. As noted by S. Juri *et al*. (2024), new qualitative threats also contribute to quantitative challenges, as climate change, soil and natural resource degradation, increased socio-economic inequality, and growing instability in agricultural and food markets undermine the resilience of food systems. Socio-economic transformations also affect the situation. Accelerated urbanisation, with more than 55% of the population living in urban agglomerations, is reducing the amount of agricultural land and increasing dependence on complex global supply chains. As noted by T. Varzakas & S. Smaoui (2024), economic inequality remains one of the key factors of food insecurity: approximately 9.2% of the global population lives in extreme poverty, while more than a quarter of the population faces moderate or severe food insecurity. Gender inequality and limited access to education for smallholder farmers in developing countries further impede the adoption of innovative and sustainable agricultural practices. Regarding climate risks, O. Ndehedehe *et al*. (2025) confirmed the substantial impact of extreme events on water resources. The study emphasised active, innovative implementation rather than response. Successful cases of water consumption reduction by 90% demonstrate that strategic management should prioritise technologies that reduce dependence on vulnerable resources.

Traditional agricultural production models, particularly intensive farming, increase environmental impact on natural systems. According to FAO (2018), agriculture produces approximately 24% of global greenhouse gas emissions, including methane from livestock and emissions related to deforestation. Excessive use of pesticides and mineral fertilisers causes soil degradation and water pollution, while the dominance of monocultures reduces agrobiodiversity. The historical example of the "green revolution" in India illustrates this contradiction: M. Crippa *et al*. (2024) noted that despite significant increases in crop yields, the long-term consequences included the depletion of up to 40% of agricultural land in the state of Punjab. From an economic perspective, such production models often prove unsustainable, as small farmers face high resource costs and limited access to market infrastructure. Sustainable food production concept offers an alternative approach, which the FAO (2018) defines as a system that ensures food security and adequate nutrition for all while preserving the economic, social and environmental foundations for future generations. The implementation of this concept involves the reduction of environmental pressure, the conservation of natural resources, the improvement of the economic viability of agricultural production and the enhancement of social justice. In this context, strategic management becomes crucial in the integration of technological innovations (precision farming, artificial intelligence (AI) and blockchain), effective policy instruments and social initiatives into a comprehensive model of food system transformation. In the analysed studies, researchers insufficiently addressed integrated models of strategic management that would combine environmental, social and economic aspects in the context of Ukraine, especially in the context of military risks and regional disparities. Most studies address individual challenges (climate, soil or inequality), ignoring comprehensive tools for transformation at the national level, which necessitated the study. Therefore, the research relevance of efficient strategic solutions that can be scaled in both global and local contexts, covering the specificities of individual regions to overcome global and regional challenges such as climate risks, high technology costs, skilled labour shortages and geopolitical conflicts, is determined. The study aimed to conduct an analysis of the principles of sustainable food production, identify the main challenges and formulate strategic recommendations for overcoming them at the global and regional levels in the context of Ukraine.

MATERIALS AND METHODS

The methodological basis of the study was based on the use of a mixed approach to conduct an in-depth analysis of the principles of sustainable food production, identify key challenges and barriers to their implementation, and develop practical recommendations for strategic management in various agricultural and food models. The analysis of previously published interviews, in particular by S. Juri *et al*. (2024), M. Crippa *et al*. (2024), and D. Saccone & E. Vallino (2025), was conducted using a set of criteria based on the role and sphere of influence of stakeholders to ensure the representativeness of food system levels. In particular, the samples covered a range of experts and practitioners, from farmers to representatives of international organisations. A key element was to achieve data integrity, i.e. the interviews had to contain "different perspectives and expectations" on critical aspects of sustainability, such as technological innovation, social justice (e.g. gender-sensitive policies) and institutional practices. The findings from the interview material were integrated with other secondary sources. These sources included official reports from leading international organisations (FAO, IPCC, UNEP, OECD, World Bank) as well as international open databases. An analysis of cases in countries such as the Netherlands, Ukraine and Denmark (Europe), Brazil, the United States and Costa Rica (America), China, Japan, India (Asia), Zimbabwe, Ethiopia and Kenya (Africa), as well as several others (including Bangladesh and Ghana), was used to identify both successful models for implementing sustainable solutions and typical problems that hinder progress in the EU and worldwide.

To develop scenarios for the development of the system, a scenario modelling method was used, combining elements of expert assessment and simulation analysis. At the first stage, key forces and factors of uncertainty were identified based on a review of the literature and expert consultations (using the Delphi method). At the second stage, a morphological analysis of possible combinations of factors was conducted, which was used to form a coordinated set of alternative development scenarios, in particular, the "catastrophic climate shock" scenario. Further assessment of the scenarios was conducted by simulation modelling of their potential consequences for the sustainability of the system using specific indicators. The key advantage of the mixed approach was the integration of qualitative and quantitative data. This synthesis provides a more complete and reliable overview of the analysed phenomenon, creating a basis for practice-oriented recommendations for strategic management of sustainable food production. The study of sustainable food production used comparative analysis to identify differences and common patterns in strategies implemented in different socio-economic and geographical contexts. This approach was used to assess how specific factors – from political institutions and technological infrastructure to climatic conditions and cultural norms – shape the characteristics of sustainable agricultural production. A comparison of practices in developed and emerging countries was used for a differentiated analysis of universal and context-dependent solutions.

The comparative analysis process in the study was based on a comprehensive set of criteria. The selection of regions and case studies was determined by the main criterion – representativeness in terms of the diversity of agri-food models, which was used to compare countries with high-tech intensive agriculture (such as the Netherlands) with countries with developing agricultural systems (such as Ethiopia or India). The comparison was conducted using key sustainability metrics, using systematised data from primary and secondary sources, including national statistics, scientific research and field observations. The main subject criteria for comparison included environmental footprint (assessment of greenhouse gas emissions, resource use and Life Cycle Assessment (LCA) results), technological readiness (level of implementation of sustainable and regenerative agriculture, as well as economic barriers), governance and policy (effectiveness of legislative changes, subsidies and institutional practices), and socio-economic aspects (including analysis of social justice and gender-sensitive policies). The integration of these approaches identified systemic conflicts and points of agreement between different priorities – for example, between increasing productivity and conserving natural resources, or between economic efficiency and social inclusion. This approach was used to develop strategies that simultaneously meet the requirements of environmental sustainability, economic feasibility and social justice. It also reinforces the correlation between science and practice, providing a basis for decision-making based on comprehensive and objective information.

RESULTS

Technological innovations in the strategic management of sustainable food production

Technological innovations are a central element in the strategic management of food systems, which ensure transition to sustainable (SFS) and adaptive models. Their strategic impact is evident not only in increased operational efficiency, but also in a fundamental shift in approaches to planning, risk management, transparency and addressing global challenges. The transformative power of technology depends on economic and administrative strategies, social needs and support across a wide range of societal and structural forces. Within the framework of strategic management, they act not only as tools for improving efficiency, but also as elements of systemic transformation of the food sector.

One of the most developed technological areas is precision farming (PF) and digital agriculture, which represent the integration of sensor systems, the Internet of Things (IoT), satellite monitoring, AI and machine learning algorithms for microzonal resource management. The use of advanced data analytics and computer vision for targeted application of resources, such as spraying weeds with up to 90% savings in agrochemicals, is radically transforming corporate business models. The strategy of agricultural producers and equipment suppliers is shifting from selling physical volumes of resources to selling "results" or "services". This requires a strategic shift from the maximisation of gross production volume to the optimisation of margins while minimising environmental externalities. Management methods prioritise data as a key production asset, and strategic planning is shifting from annual to seasonal and operational, based on real-time models (digital twins), requiring significant investment in digital infrastructure and expertise.

The integration of satellite data into control mechanisms automatically monitors agricultural plots to confirm compliance with financial support (subsidy) conditions. This transforms public administration from resource-intensive manual control to risk-oriented and transparent monitoring. Strategically, the government is shifting from controlling the costs of economic entities to controlling results and compliance with environmental standards, thereby increasing the efficiency of budget funds. Research also emphasises the significant improvement of strategic planning in the agricultural sector through the use of short-term yield forecasting algorithms based on highly spatially detailed data (Pokal *et al.*, 2024), which facilitates adaptation of cultivation strategies to changing environmental conditions. IoT-based precision irrigation technologies can significantly improve water efficiency (Xing & Wang, 2024), which is a critical strategic imperative for regions prone to desertification (e.g., southern Ukraine). The strategic integration of ICT into national programmes requires support both in terms of digital infrastructure and through the development of institutional knowledge management mechanisms to ensure the widespread adoption of innovations.

Development of biotechnology, including genetic engineering, cultured meat and alternative protein sources, is also relevant. The vector of development of biotechnological solutions is a fundamental driver of strategic restructuring of food systems. These technologies, which involve manipulation at the cellular level and the creation of food and feed substitutes, go beyond technological change to become a key factor in strategic management. At the corporate level, the success of innovative areas offering alternative proteins poses an existential challenge to traditional agribusiness conglomerates. Their strategy is inevitably transforming: from the former desire for a monopoly on protein to the need for strategic diversification of protein sources. This requires large companies to internalise disruptive innovations to minimise the risk of market displacement and necessitates a reassessment of the value of tangible assets (farms, land), which can be replaced by high-tech, resource-saving production facilities, radically changing the approach to capital investment and long-term planning.

At the sectoral and government levels, biotechnology is becoming critical for macro-risk management. Livestock management is transitioning to biological and climate risk management related to animal health and greenhouse gas emissions. Genetic engineering facilitates a preventive adaptive strategy. This is a strategic method for the reduction of agrochemical use and the stabilisation of crop yields in extreme climate conditions, making agriculture more sustainable (Gupta, 2024). In addition, for large economic entities, the implementation of national programmes to increase the production of alternative proteins is a direct strategy for national food independence and reducing geopolitical risks, aimed at minimising critical dependence on international imports of key raw materials. The development of cell-based agriculture and plant-based alternatives is an imperative for environmental sustainability: the production of these proteins requires significantly fewer resources, forcing governments and institutions to strategically rethink the parameters of natural resource efficiency. Strategic management is moving away from a volume-based, extensive strategy (increasing acreage) to a cost- and resource-efficient strategy (precision agriculture), where the metric of success is determined not by gross production, but by minimising external environmental effects and increasing productivity per unit of resource used.

Regenerative agriculture (RA) is becoming the third basis of technological transformation of sustainable food systems. RA is a set of agricultural practices (such as no-till, mulching, crop rotation, and cover cropping) that are strategically aimed at improving soil health and increasing its organic carbon content, transforming soil from a simple carrier into a strategic asset and carbon reservoir. Investments in programmes that encourage farmers to adopt CSA practices reflect a strategic shift from simple procurement management to supply chain sustainability management. Large processors and retailers are strategically investing in the sustainability of their raw material base, not only for environmental reasons, but also to hedge supply risks and manage financial attractiveness. This simplifies access to cheaper green financing (ESG investments) and strategic management of reputational risks in response to growing consumer demand. Healthy soil becomes an insurance policy against climate volatility, integrating into financial models as an investment in sustainability rather than just an operating expense. The integration of soil health improvement measures into national emission reduction strategies (as is the practice in Canada) is a prime example of the strategic positioning of the agricultural sector. The state is strategically transforming the agricultural sector from a mere food producer into an active carbon sink. This creates new opportunities for international climate finance and increases the sector's competitiveness in global markets, which are increasingly demanding carbon-neutral products. Technological innovations alone are insufficient for a complete strategic transformation of food systems. They must be supported by changes in policies and the regulatory framework, the creation of market incentives, the provision of stable financing, and the formation of public trust in new technologies.

Political and economic mechanisms of strategic management

The development of strategic frameworks, roadmaps, key performance indicators (KPIs) and development scenarios in the field of political and economic food management mechanisms is a multi-stage, cyclical process that governments and institutions implement based on systematic analysis, integrating political decisions and economic instruments to achieve sustainability and security goals. The strategic framework is first established, beginning with an analysis of the food security system and vulnerability assessment using UN SDG reporting and SWOT/PESTEL analysis. This stage provides a long-term vision and goals (e.g., transition to a resource-efficient system), which are then validated through multi-stakeholder consultations with science and business. The integration of a long-term vision based on ESG principles and the UN Sustainable Development Goals (SDGs) into national and regional strategies is the basis of further development. The European Union's Farm to Fork Strategy is a notable example of specific targets for reduction of pesticide, antibiotic and fertiliser use, as well as an increase in organic farming by 2030 (Moschitz *et al.*, 2021). Another example is Singapore's National Food Security Strategy ("30 by 30"), which aims to produce 30% of the national food needs locally by 2030 through intensive investment in vertical farms and aquaculture in a land-constrained environment (Calvo-Baltanás *et al.*, 2025). Similarly, China's "Number One" strategy focuses primarily on self-sufficiency in staple crops based on a strategic framework to tightly control acreage and government procurement (Shih *et al.*, 2025).

The integration of social innovations that ensure the inclusiveness of strategic management and the sustainability of local communities is a substantial vector for reinforcing political and economic mechanisms. In this context, the example of the Indian association SEWA (Self-Employed Women's Association) is noteworthy, as it demonstrates how a collective organisation of self-employed women farmers can overcome structural barriers to access to financial resources, land rights and markets. SEWA transforms social capital into tangible economic leverage through cooperation mechanisms, incorporating small producers in the formation of value chains on an equal footing with large agricultural holdings. A similar social trajectory is demonstrated by organic coffee cooperatives in Costa Rica, where strategic management is based on the principles of fair trade and shared responsibility for ecosystems. These cooperatives act as social stabilisers, providing not only environmental certification of products, but also funding for health care and education for community members, making agricultural production the foundation of regional prosperity. At the same time, rethinking the role of FAO (2022) Farmer Field Schools exceeds the scope outside of political interpretation as an instrument of state support. Within the framework of strategic management, FFS act primarily as an institutional mechanism for building social capital through horizontal learning and peer-to-peer problem solving. In contrast to traditional top-down models, these frameworks form a networked structure of interaction, where sustainable soil cultivation methods and plant protection become a public asset. This transforms farmers from objects of state regulation into strategic change agents capable of self-organisation and collective adaptation to climate risks. Thus, the combination of economic incentives with a substantial social foundation, based on cooperation and knowledge sharing, becomes a decisive factor in the success of any national strategy for sustainable food production, ensuring legitimacy and long-term sustainability in a changing global environment.

Next, the strategic vision is transformed into specific roadmaps by deconstructing the goals into medium-term programmes and short-term tasks. At this stage, political and economic mechanisms are applied directly: economic levers are used in the form of subsidies for regenerative agriculture, tax breaks and R&D funding, as well as political levers through the establishment of regulatory standards (e.g. pesticide restrictions) and land policy. The success of roadmaps depends on adaptive governance mechanisms that can be used for flexible revision of strategies based on empirical data, as was the case with the adaptation of Canada and New Zealand's national food strategies in response to the logistical shocks caused by the COVID-19 pandemic. India's roadmap for sustainable development of the agri-food sector for the period up to 2030 provides for a clear division of responsibilities between the central government, states and private businesses, especially in water management and digitalisation of farming services (Chand, 2022).

At the same time, KPIs that are critical for monitoring progress are being established. Modern KPIs cover three dimensions of sustainability: economic (e.g., price volatility and agricultural export index), environmental (GHG emissions per unit of production based on LCA and percentage of land with regenerative practices) and social (food accessibility index and malnutrition rate). Denmark uses detailed KPIs for reducing greenhouse gas emissions in agriculture, which are directly linked to subsidy programmes and investment priorities (Schokker *et al.*, 2022). Another example is the World Bank and FAO, which use the Food Security Index as a KPI to assess the effectiveness of national investments in agriculture (MOPAN, 2024), which can be used for progress comparison between countries and financial assistance to be adjusted. Moreover, international giants (such as Unilever) use KPIs on the percentage of raw materials sourced from renewable sources and integrate them into their ESG reports (Tan, 2025), creating additional pressure on governments to set appropriate national standards. This ensures transparent monitoring and adaptive management based on these measurements.

The cycle is completed by the development of scenarios for the improvement of the sustainability of the system. Governments conduct scenario modelling of several possible future scenarios (from climate disasters to sustainable growth), assess the sustainability of existing mechanisms under these conditions, and develop adaptive policies and response plans (e.g., the creation of strategic food reserves) that are activated when certain “triggers” are reached. Governments model various development scenarios (e.g., “catastrophic climate shock” or “global supply chain disruption”) to assess the stress resilience of national food reserves and infrastructure. A typical example is the modelling of the impact of drought or flooding on the yield of major crops and the assessment of the need for strategic reserves, which is regularly conducted by the FAO and the International Food Policy Research Institute (IFPRI). For instance, Australia employs scenario analysis to assess the impact of different levels of extreme weather events on export markets and domestic water supplies, which has led to the development of diversified investment programmes in irrigation technologies and early warning systems (Christopher *et al.*, 2025).

Political and economic instruments are central in shaping an institutional environment that promotes sustainable food production. These include support for farmers, fiscal incentives, international agreements and aid programmes to improve the resilience of food systems in the context of climate and economic risks. Their efficiency significantly depends on the coherence of strategic management, the availability of resources, and consideration of the specificities of the local context (Sgarbi & Nadeu, 2023). Subsidy policies aimed at promoting sustainable practices have a significant impact on farmers' adaptation to climate change and transition to environmentally friendly methods. Programmes such as CAP in the EU, PM-KUSUM in India or tax incentives in the US encourage the adoption of precision farming, renewable energy and organic farming; however, they also face several institutional barriers (European Commission, n.d.a; MNRE, 2022; McFadden *et al.*, 2023).

International agreements, including the Paris Agreement and SDG 2, are used as a basis for global efforts, but implementation remains fragmented. FAO (2018), CGIAR (2022) and UNFCCC (n.d.) programmes provide technical assistance and funding, but coverage of beneficiaries in low-income countries remains limited. Smallholder support programmes are substantial, especially in developing countries. Initiatives such as PSNP in Ethiopia, PMFBY in India, or IFAD (2022) microfinance help overcome the vulnerability of rural households and promote social inclusion (World Bank, 2021). However, limited access, high rates, and weak institutional infrastructure remain barriers. In China, the introduction of agro-environmental subsidies (2022-2025), including grants for integrated land use, has reduced erosion by 12% in pilot regions. Strategic management at the provincial level has contributed to more efficient allocation of funds (Chang & Wang, 2023).

In Kenya, Pula (n.d.) digital microinsurance programme covers more than 6 million farmers and is linked to satellite data. This reduces transaction costs and improves drought resilience (Table 1).

Table 1. Political and economic measures for sustainable production: examples, tools, efficiency

Tool	Example of a country/region	Implementation method	Effects and risks
Ecological subsidies	EU (CAP 2023)	30% of the budget for green practices	More than 20% organic land, fewer pesticides, bureaucracy
Renewable energy	India (PM-KUSUM)	Solar pump subsidies	10% less CO_2 emissions, but insufficient coverage
Tax breaks	USA (USDA 2023)	Tax reduction for precision farming	More than 25% of implementations in 5 years, but not available to everyone
International treaties	SDG 2, Paris Agreement	Global commitments, financing	10 billion USD through the GCF, but with insufficient implementation
Climatic agronomy	CGIAR	New resistant varieties	15% higher yield, limited coverage
Farmer support	Ethiopia (PSNP), India (PMFBY)	Microloans, insurance, grants	15% more income, but low accessibility
Strategic management at the provincial level	China, pilot regions	Introduction of agri-environmental subsidies (2022-2025), including grants for integrated land use	12% reduction in erosion, increased efficiency of resource allocation
Development of software linked to satellite data	Kenya	Digital microinsurance programme from Pula	Lower transaction costs and improved drought resilience

Source: compiled by the authors based on FAO (2018), World Bank (2021), MNRE (2022), CGIAR (2022), IFAD (2022), UNFCCC (n.d.), F. Sgarbi & E. Nadeu (2023), Y. Chang & S. Wang (2023), J. McFadden *et al*. (2023), Pula (n.d.), European Commission (n.d.a)

In contrast to international cases analysed, where political and economic instruments are implemented in conditions of relative institutional stability, their application in Ukraine differs significantly under the influence of martial law. State subsidies are being redistributed in favour of food security, and the "Affordable Loans 5-7-9%" programme has been adapted to the needs of the agricultural sector. At the same time, funding remains limited and access to resources is uneven, particularly for farmers in the eastern regions of the country. This indicates a decline in the effectiveness of standard financial instruments in crisis conditions and highlights the need for their flexible combination with direct support for vulnerable groups and international coordination mechanisms. Incorporating territorial differences, the level of institutional maturity and the social structure of agricultural systems, the strategic integration of such measures forms a more sustainable basis for the transformation of food systems in times of global crisis.

Social aspects of sustainable food production

Social factors are substantial in shaping sustainable food systems, as they go beyond economic efficiency to promote community engagement, expand access to knowledge and technology, and ensure social justice and equal opportunities. Strategic management of the food sector cannot be successful without deep integration of social capital. One of the key areas is the development of educational initiatives that transform the traditional model of knowledge transfer. Field school programmes and online courses supported by international organisations demonstrate high potential for democratising access to knowledge on agroecological and regenerative practices. The use of digital platforms (mobile applications) in African countries has become an example of how accessible training can increase crop yields and operational efficiency on farms. The knowledge management strategy is shifting from centralised expertise to decentralised, scalable self-learning. This is also crucial for gender strategy, as expanding the participation of women, who represent a significant portion of the workforce, in training programmes directly increases the overall productivity of the sector.

Integration of local communities into decision-making through cooperative forms of management improves sustainability at both the microeconomic and sectoral levels. The creation of organic farmers' cooperatives in Latin American countries or the involvement of communities in the restoration of degraded land in East African countries not only improves the economic situation of participants but also strengthens the food security of millions of people. Cooperative models, including the institutional participation of marginalised groups, are a strategy for increasing market access and bargaining power for small producers. For the state, cooperation is an effective mechanism for internalising externalities (e.g. soil restoration) and reducing administrative costs for supporting small farms. Fair trade mechanisms that provide producers with stable prices and premiums are a strategic tool for managing ethical and financial risks in supply chains. More than 1.9 million farmers in 70 countries receive economic and social benefits from participating in certified chains (Jodrell & de Bruin, 2024). Therefore, producers can reinvest premiums into environmental projects and local infrastructure, which in turn minimises the risks of supply instability for end processors. For large market actors, investment in fair trade is not charity, but a strategy for managing reputation capital and ensuring the long-term sustainability of the raw material base.

Despite successful examples, there are significant universal barriers: limited access to educational resources in remote regions, high certification costs, and a lack of start-up capital for cooperation. Strategic management requires an integrated approach: combining educational programmes with government support and the introduction of digital technologies. The effectiveness of these measures varies depending on the institutional context. In countries with developed infrastructure, regulatory mechanisms, and subsidies that create institutional incentives for sustainable practices are central. In developing countries, the focus is shifted towards social mobilisation and expanding access to knowledge and markets. The most sustainable results are achieved when these approaches are integrated, as they address financial, institutional and cultural barriers that hinder the expansion of successful models. Thus, strategic management should address the institutionalisation of social inclusion as a necessary prerequisite for economic and environmental sustainability. Modern strategies for sustainable food production show significant progress, but their implementation requires systemic support (Table 2).

Table 2. Integration of sustainable food production approaches: measures, regional cases and KPIs (2021-2025)

Tool	Example of a country/region	Implementation method	Effects and risks
Technological	EU	Introduction of precision farming in the Netherlands	25% higher yield; 30% less water consumption; 20% less fertiliser use
	Kenya	Mobile agricultural applications (iCow, DigiFarm)	15% higher yield; 20% higher household income
Political and economic	EU	Subsidies for sustainable practices (CAP, Farm to Fork Strategy)	A 35% increase in organic farming areas by 2030.
	India	Agro-environmental subsidies (PM-KUSUM, India)	20% increase in the share of sustainable farms; 30% increase in access to solar systems
Social	Global	FAO Farmer Field Schools Programme	1 million trained farmers in 90 countries
	India	SEWA women cooperatives	1.5 million women with access to markets; 25% increase in cooperative profits
	Costa Rica	Organic coffee cooperatives	20% increase in farmers' income; greater use of sustainable practices

Source: compiled by the authors based on Indian Council of Agricultural Research (n.d.), T. Reardon *et al.* (2022), FAO (2022), IFAD (2022), V. Mehta (2023), E.M.B.M. Karunathilake *et al.* (2023), Fairtrade International (2024), D. Jodrell & W. de Bruin (2024), T. Issayas & Y. Lemma (2025)

Efficient in developed countries, technological and policy measures require institutional adaptation for the global South. Social initiatives have a long-term impact, promoting social justice and inclusion, but require comprehensive support to expand. Relevant social and institutional mechanisms for sustainable agricultural production are also being developed in Ukraine. The National Strategy for Digital Transformation of the Agricultural Sector until 2030 includes measures to expand access to knowledge and innovation in rural areas (Law of Ukraine No. 1163-r, 2023). The cooperative movement, supported by the Ukrainian Agrarian Council, is increasingly substantial in enhancing social inclusion and collective resilience (Agroreview, 2025). The development of cooperatives also strengthens the sustainability of the agricultural sector, especially in times of war, when cooperative forms help to pool resources, restore logistics and ensure food security at the local level.

Fair Trade principles are implemented through national and international programmes that focus on training, cooperation and support for SMEs in the agricultural sector. Ukraine is still poorly integrated into global Fair Trade supply chains. However, some organic producers are already obtaining relevant certification. The main barriers remain limited access to knowledge in remote villages, high certification costs, lack of capital, and weak institutional support. These problems can be addressed by accelerating digitalisation, expanding state and international support programmes, and increasing the participation of non-governmental organisations. The most sustainable results are achieved when several approaches are integrated: educational programmes, subsidies, the introduction of digital solutions, and institutional reforms. Elements of these models are gradually taking shape, but for a large-scale effect, institutional consolidation of strategies such as the development of rural digital platforms and the introduction of training programmes at the community level is necessary. Integration of educational, digital and cooperative strategies with the support of the state and international partners creates conditions for the social sustainability of food systems in Ukraine and forms the prerequisites for an inclusive and equitable agricultural revival. Thus, the integration of approaches demonstrates that the maximum effect is achieved at the intersection of technology, social policy and institutional regulation. Notably, strategic management is central for such integration, ensuring coordination of activities, risk assessment and adaptation of decisions to the regional context.

Strategic management in food systems: From classical models to integrated approaches

The historical evolution of strategic planning models in the agricultural and food sector reflects a fundamental paradigm shift from linear growth to systemic sustainability. The classical planning models that dominated the last century were based on the assumption of infinite access to natural resources and the priority of increasing production volumes without due consideration of environmental and social constraints. However, with the onset of the 21st century, such approaches have become inadequate due to the intensification of climate crises, critical resource depletion and growing pressure from stakeholders. This has led to an objective need to transition to systemic approaches, where the strategic framework includes ESG (Environmental, Social, Governance) principles, the triple bottom line (TBL) concept, and the long-term benchmarks of the Sustainable Development Goals (SDGs) (Chopra *et al.*, 2024).

Modern concepts of sustainable development integration are based on a transition from short-term horizontal planning to transdisciplinary thinking based on scenarios and cyclicality. Strategic documents must also address planetary boundaries and social thresholds, which are embodied in the use of the "donut sustainability" framework (Turner & Wills, 2022). A central element of this process is the introduction of Life Cycle Assessment (LCA), which provides scientific forecasting of the consequences for products and technologies. The use of LCA can evaluate the results of implementing regenerative farming methods, which can reduce CO_2 emissions by 15% compared to traditional systems, while increasing resource efficiency and resistance to external stresses.

Institutional mechanisms for the implementation of sustainable management strategies form a complex architecture adapted to modern challenges. The development of a priority matrix to identify significant ESG issues and correlate them with stakeholder expectations and regulatory trends is central at the planning level. Strategic environmental assessment performs a predictive control function, analysing the impact of programmes and investment decisions on ecosystems and social groups even before they are implemented. Scenario planning, especially in its climate-oriented modification using system dynamics methods (Vensim or Stella software), integrates time uncertainties into management thinking. This creates adaptive behaviour models in conditions of instability, including parameters of infrastructure vulnerability and agrosystem stress resistance. Integrated reporting acts as a mechanism for transparency, aligning the financial and non-financial logic of activities, demonstrating transformations and long-term effects through the prism of public trust and inclusiveness of decisions. Assessment of the effectiveness of these strategies requires a system of quantitative KPIs, which serve as operationalisers of sustainable strategies. Such indicators can be used for real-time monitoring, control and decision-making, ensuring transparency and accountability of the process. A set of industry KPIs for sustainable food production is presented in Table 3.

Table 3. Strategic KPIs for sustainable food production

Area	KPI indicator	Unit of measurement	Explanation/example	Source/method
Ecological	Production carbon footprint	kg CO_2-equiv. / t of produce	Overall emissions	GHG Protocol, ISO 14067
	Production water footprint	l / kg of produce	Water accounting by type: Blue, green, grey	Water Footprint Network
	Soil degradation index	% of lost fertility	Assessment of erosion, compaction and contamination	FAO, National Soil Service
	Share of organic/eco-certified areas	% of total sown area	Direct indicator of sustainable practices	Global Organic Monitor, national statistics
Economic	Added value per unit of natural resource	USD/m³ of water, USD/ha of land	Eco-efficiency in the production cycle	WBCSD, FAO
	Share of sustainable procurement in the supply chain	% of contracts with certificates	For instance, Rainforest Alliance, FSC, etc.	Corporate reporting, GRI
Social	Percentage of employees covered by the social security system	%	ILO, OOH standards	GRI, local labour inspections
	The proportion of women in the management of agricultural enterprises	%	Gender inclusiveness indicator	OECD, UN Women
	Level of compliance with land use rights	% of agreements reached	Legitimacy and stability of the lease	World Bank Land Governance Framework
Institutional	Availability of an integrated LCA/ESG/ system (methodology for assessing the full life cycle of products (from field to shelf))	binary (yes/no)	Reflects the maturity of consistency management	GRI, ISO 14001/14040, IR Framework (international frameworks for non-financial reporting)
	Frequency of sustainable development strategy updates	times/year or planning cycle	Reflects adaptability to external risks	Internal audit, corporate documents
	Level of compliance with SDGs (based on self-assessment)	index from 0 to 1	Integration with the UN's global goals	SDG (Sustainable Development Goals)

Note: GHG Protocol (Greenhouse Gas) – provides most used standards and guidelines for greenhouse gas accounting; ISO 14067 – international standard, establishes requirements for calculating and reporting the carbon footprint of products; Global Organic Monitor – monitoring of the global market for organic products and its trends or the area of agricultural land on which organic farming is practised; WBCSD (World Business Council for Sustainable Development) – World Business Council for Sustainable Development, a global network of more than 250 leading companies that view sustainable development as a key factor in competitiveness; GRI (Global Reporting Initiative), IR (Integrated Reporting Framework), ESG (Environmental, Social, Governance) – international frameworks for non-financial reporting; OECD (Organisation for Economic Co-operation and Development) – a forum and knowledge centre for sharing data, analytics and best practices in public policy; LCA (Life Cycle Assessment) – a methodology for assessing the entire life cycle of a product (from field to shelf)

Source: compiled by the authors based on World Resources Institute & World Business Council for Sustainable Development (n.d.)

A comparison of international practices demonstrates the high efficiency of integrated approaches. In the European Union, the Farm to Fork strategy sets a goal of reducing the use of chemical pesticides by 50% by 2030 (European Commission, n.d.b), while India's PM-KUSUM programme is achieving a 10% reduction in CO_2 emissions through solar transformation (MNRE, 2022). Technological modernisation in the United States through the use of drones has reduced pesticide use by 20-30%, and in the Netherlands, digital platforms are demonstrating the potential to reduce water consumption by 90%. Social integration is most evident in the experience of Costa Rica, where the development of organic coffee cooperatives has led to a 15% increase in exports (FAO, 2018). It is necessary to improve the analysis of social aspects through the cases of SEWA women's cooperatives in India, which have become a model of inclusive growth. Moreover, in a social context, the institutional consolidation of FAO (2022) Farmer Field Schools programmes should be considered, which ensures the stability of rural communities through the mass training of farmers. In addition, blockchain initiatives in India show a 30% reduction in corruption in the distribution of subsidies, confirming the importance of combining technology with social justice (NITI Aayog, n.d.).

Despite successful examples, there are critical challenges and constraints that hinder sustainable transformation. Globally, climate threats in African regions are projected to reduce crop yields by 20-30% (Simane *et al.*, 2025). In Ukraine, the process of integrating sustainability remains fragmented due to a weak methodological base and institutional dependence on outdated models (Path Dependency), which leads to a decline in the level of organic carbon in soils. Military conflict creates multidimensional risks that traditional strategies cannot simultaneously mitigate. The solution to these problems for Ukraine lies in the implementation of a "digital twin" that combines data on mining, soil conditions and logistics for predictive management. Ukrainian policy should be supported by successful practices: expanding digital services similar to Kenya (where iCow mobile applications increased yields by 10-15%), developing cooperatives based on the SEWA and Central American models, and institutionalising FAO Farmer Field Schools educational programmes. A combination of economic incentives, similar to EU measures, with technological and social innovations will form a development model that combines economic efficiency with environmental sustainability and national security in the context of global transformations of the 21st century.

Cases of strategic management in food systems: Successes and failures

An analysis of empirical cases in the field of sustainable food production shows that strategic management in this area depends not only on the level of technology or the volume of investment, but on the ability to integrate long-term sustainable development goals, incorporating local characteristics, institutional constraints and global challenges (Table 4).

Table 4. Successful cases of strategic management of food systems

Region/country	Base approach	Key strategies	Results and consequences
Netherlands	High-tech agriculture	PPP (public-private partnership), subsidies for technology, and farmer education	Tomato yield is 5 times higher than average, water consumption is reduced by 90%, and CO_2 emissions by 20%
Costa Rica	Agroecology and organic farming	Ban on GMOs, cooperatives, support for Fairtrade	15% growth in exports, 50% reforestation, and involvement of women
Ethiopia	Integrating food aid and ecological restoration	PSNP programme, satellite monitoring, farmer participation	1.5 million hectares restored, food security improved for 8 million people
Japan	Vertical farms with AI	Robotisation, hydroponics, state subsidies	-95% water, +300% productivity, no pesticides
Ukraine	ESG and closed loop	Biogas, biowaste, KPI-oriented management	CO_2 -35% by 2030, investment in bioenergy +25%

Source: compiled by the authors based on Safaricom PLC (2022), OECD (2023a; 2023b), Quarterlytics (2023), AgroNews (2025)

A range of countries have implemented successful models of sustainable food production, where close coordination between public and private structures, along with widespread innovation, is a key factor. One example is the Netherlands, where, despite a shortage of natural resources, one of these models is in place. Government incentive strategies, such as top-level sector policy, form a "triple helix" of interaction between government, academia and business. This association encourages the adoption of precision farming, IoT, drones and AI analytics in greenhouses and fields, optimising resources, reducing emissions and increasing yields (OECD, 2023a; 2023b). With government investment in agricultural R&D, subsidy programmes for agritech start-ups and strict monitoring of emissions, the Netherlands has achieved a 90% reduction in water consumption and a 300% increase in crop yields compared to the global average.

Another case of strategic success is Costa Rica, where the government is consistently implementing agricultural transition by combining a ban on GMOs, support for organic agriculture, and the development of cooperatives, especially in indigenous and mountainous regions. This approach is supported by fair trade programmes and cross-border ecotourism, which have contributed to the restoration of more than half of degraded forests and a 15% increase in the value of agricultural exports. The restoration of forests in the country has been made possible by land policies that include payments to land users for preserving or restoring vegetation (Payments for Environmental Services), as well as the introduction of a system for protecting biological corridors and a ban on logging. As a result, Costa Rica has changed from a country with one of the highest rates of deforestation in the 1980s to a regional example of environmental sustainability and leadership in organic exports (OECD, 2023a; 2023b). Spread Co., Ltd. (Techno Farm, Kyoto and Fukuroi) has introduced fully automated vertical farms: AI systems, robots, LED lighting and hydroponics, which provide a significant increase in yield while drastically reducing water consumption (by up to 95%) and eliminating the use of chemicals. Based on the analysis, the company produces up to 30,000 lettuce heads per day with minimal water consumption, and automated management has increased yields several times compared to traditional farming. In terms of strategic support, the Japanese government is promoting the Smart Agriculture initiative through inter-ministerial programmes (SIPs) and the NARO laboratory. Projects include robotics, hydroponic installations, and AI monitoring aimed at creating sustainable farms that reduce resource use and increase yields. Japanese vertical farms with AI and hydroponics are becoming a model for highly efficient and resource-saving agricultural systems through these programmes, via METI and other agencies. (Liu *et al.*, 2022).

In Kenya, the introduction of mobile agricultural technologies, including the iCow and DigiFarm platforms, as well as the active participation of women's cooperatives, resulted in a significant improvement in farming productivity and economic integration. The iCow users, especially in the counties of Uasin Gishu, Nyandarua, and Bomet, reported an increase in milk income of approximately 50,000-130,000 kg per year (approximately 400-1,000 USD), while average annual milk production per cow increased from ~1,964 litres to ~2,359 litres (i.e. ~20%) compared to controls. DigiFarm has shown rapid growth: more than 700,000 registered farmers successfully accessed loans, training and inputs via mobile phones within a year of launch, improving farm productivity and resilience. The involvement of local communities and cooperatives has contributed to a reduction in household costs of approximately 20%, particularly through optimised procurement, knowledge sharing and collective access to resources (Safaricom PLC, 2022). Despite the war, successful pilot projects were implemented in some regions of Ukraine. For instance, in the Poltava region, cooperatives of small producers, supported by USAID grants, reported an 18% increase in income. In the Lviv region, the introduction of drip irrigation and training programs increased crop yields by 23% (AgroNews, 2025). It is also worth noting the example of Ukraine: the MHP agricultural holding has become a pioneer in ESG-oriented agribusiness, selling biogas stations, a bio-waste disposal system, and digital KPI platforms. This ensures 35% reduction in CO_2 emissions by 2030 and increased energy efficiency, despite external challenges, including war and energy crises (Quarterlytics, 2023) (Table 5).

Table 5. Failed cases of strategic management

Country/region	Primary issue	Cause	Consequences
India (Punjab)	Excessive use of agrochemicals	Lack of education, monitoring, and strategic planning	Degradation of 40% of land, increased morbidity, and river pollution
Brasil	Deforestation for agricultural purposes	Priority of exports, weak interagency coordination	20% loss of the Amazon rainforest, 15% increase in CO_2 emissions, loss of biodiversity
Zimbabwe	Land reform without support	Lack of training, investment, and infrastructure	40% reduction in production, 60% increase in food insecurity
Ukraine	Lack of a strategy to support farming	Lack of monitoring of policy effectiveness. Insufficient involvement of communities in the development of local programs	Low level of fund absorption (less than 50% of planned subsidies were implemented in 2021). Only about 72% of the planned budget of 6.5 billion UAH was used

Source: compiled by the authors based on World Bank (2022), V. Kravchenko (2022), Ukraine: Largest amount of state support in 2021 received by five agriculture companies (2022), P. Greenfield (2023)

In contrast to successful examples, there are several cases where strategic management was either absent or ineffective, leading to persistent environmental, economic, and social dysfunctions. In Punjab (India), the consequences of the "green revolution" resulted in environmental and agricultural crises: despite increased crop yields, excessive use of fertilisers and pesticides, lack of effective agricultural education and lack of monitoring led to the degradation of over 40% of arable land and serious river pollution. Experts recorded a drop in organic carbon content to 0.3-0.8%, while the minimum acceptable level is 1%. This is indicated in the government report. According to the Department of Planning, about 39% of the state's territory is completely degraded, and 50% suffers from a serious deficiency of nutrients (such as nitrogen and phosphorus), which highlights the institutional inability to adapt to long-term environmental challenges.

In Brazil, the strategic emphasis on agricultural exports, accompanied by the relaxation of environmental regulations under the Bolsonaro administration, caused a major increase in deforestation in the Amazon and higher greenhouse gas emissions. At the same time, the agricultural lobby has actively influenced decision-making, undermining the national and international climate commitments. The lack of coordination between the federal government and the provinces has undermined full compliance with environmental standards and prompted a response from the international community, including import restrictions by the EU under sustainable supply chain rules (e.g., EUDR). After years of scientific observation, evidence has confirmed that under Bolsonaro's leadership, deforestation in the Amazon has reached a 15-year high, directly impacting the country's climate and global sustainability. According to INPE (Brazilian Institute for Space Research), carbon emissions from deforestation have increased significantly (from an average of 0.24 gigatons per year in 2010-18 to 0.44 GtC in 2019-2020, respectively), and foreign buyers, especially from the EU, have expressed serious concerns about the origin of imported products and their environmental responsibility (Greenfield, 2023). Thus, the priority on short-term gains and weak institutional infrastructure resulted in a significant deterioration of the environmental situation in the country and increased pressure from the international community, primarily the EU. Similar examples are observed in Zimbabwe, where land reform was implemented without strategic support: the lack of investment, agricultural infrastructure, and support for new farmers led to a 40% drop in crop yields and a 60% increase in food insecurity (World Bank, 2022). In Ukraine, the government's 2020-2022 programs to support farming often lacked a specific implementation strategy. Low absorption of funds (less than 50% of planned subsidies were implemented in 2021) State programs to support farming in 2021 faced significant underfunding; in fact, only about 72% of the planned budget of 6.5 billion UAH was used, and the lack of effective monitoring and corruption schemes significantly reduced the effectiveness of these measures (Kravchenko, 2022; Ukraine: Largest…, 2022).

Analysing these cases, several critical conditions for strategic success in food systems can be identified. Effective systemic management with clear interagency coordination is vital. Programs that integrate agricultural innovation, environmental goals, and social mechanisms demonstrate the greatest resilience and adaptability. Strategies need to be localised. Approaches that factor in the local context, education levels, infrastructure readiness, and cultural characteristics are more sustainable than universal or export-oriented models. KPI-based assessment is key. Quantitative indicators such as carbon footprint, hectares restored, and food security index can be used to manage results and adjust policies in real time. Ukraine needs a multi-level strategy that combines decentralised planning based on up-to-date data with the introduction of innovations incorporated into educational and financial systems. It is necessary to ensure the active participation of local producers in collaborative management processes and to introduce a comprehensive performance assessment system that incorporates indicators of yield, income level, environmental footprint, and community engagement. Thus, sustainable strategic management is not a set of policies, but a dynamic system that demands a balance between the interests of the economy, the environment, and society. Successful cases point to the potential of sustainable models as a driver of economic growth, while unsuccessful examples point to the high cost of ignoring sustainable development and strategic analysis. In the case of Ukraine, future sustainability requires an adaptive, transparent, regionally sensitive management system that incorporates international experience but is based on local potential.

Comparative analysis of regional strategies for sustainable food production

Determination of the differences in regional approaches to sustainable food production can not only reveal effective models, but also adapt them to the conditions of individual countries, including Ukraine. The European Union, the United States, Asia, and Africa demonstrate varying degrees of institutional maturity, resource availability, and political will, which determine the trajectories of food system development. The EU (e.g., the Netherlands, Denmark) emphasises technological leadership, bioeconomy, digitalisation, and institutional frameworks – from Farm to Fork strategies to the Green Deal (European Commission, n.d.b). These approaches are supported by a comprehensive system of subsidies and research centres (e.g. Wageningen University), digital platforms and certification mechanisms, which ensure sustainability to be measured and managed using KPIs. The United States is relying on private investment, agribusiness holdings, and USDA initiatives. Although advanced precision farming technologies are being developed, structural vulnerabilities remain: the dominance of large farms, dependence on monocultures, and low environmental sustainability in some regions. African and Asian countries such as Ethiopia, India, and Kenya are demonstrating potential through low-cost technologies, cooperative movements, local community participation, and international programmes. In Kenya, for example, digital platforms and mobile technologies provide access to credit and agricultural advice, increasing yields and incomes by 25-40% (IFAD, 2022). In India, the PM-KUSUM programme (subsidies for solar installations) has reduced CO_2 emissions and costs, but requires transparent monitoring (Indian Council of Agricultural Research, n.d.).

Ukraine, being at the forefront of global trends and local challenges, is a special case. On the one hand, the country has high agro-industrial potential, fertile black soil and an export orientation. On the other hand, it suffers from institutional instability, limited access to finance, vulnerability to external shocks (including war) and weak coordination of sustainable initiatives (Escoto, 2020). Although Ukraine has introduced elements of sustainable agriculture – organic production, pilot digital farms, precision irrigation projects – these practices still cover only about 5-7% of the total sector (Ivashura *et al.*, 2022). In addition, there is no comprehensive mechanism for monitoring sustainability and strategic management at the national level, which limits the scaling up of successful practices. Therefore, Ukraine can use an adaptive model that combines the best practices of the EU (institutional support and regulatory framework), African countries (inclusive approaches and cooperation), and the US (technological transformation). However, this requires investment in science, sustainability standards, digital transformation, and a KPI system at all levels of government.

Global cooperation is a catalyst for the transformation of food systems towards sustainable development. International organisations, including FAO, CGIAR, IFAD and GCF, are actively investing in projects aimed at reducing vulnerability, developing agroecology and adapting to climate change. Examples include GCF investments in biofarms in Asia and Africa, CGIAR (2023) platforms for crop genomics, and FAO (2018) initiatives on agro-landscape planning. For Ukraine, cooperation with the FAO, GEF, and the European Investment Bank (EIB) has become particularly relevant in the context of the war. Programmes to support farmers, restore logistics, and introduce alternative technologies (mobile elevators, drones) have become not only a factor for survival, but also an incentive for more sustainable production (Escoto, 2020). However, access to international assistance requires institutional maturity, transparency, and strategic integration into national policy. The lack of a single coordination centre for sustainable agriculture in Ukraine, fragmented policies, and competition between agencies weaken the effect of international initiatives. The introduction of a national platform for sustainable agricultural development with the participation of civil society organisations, the Ministry of Agrarian Policy and the business sector could strengthen strategic management and the integration of global resources into national priorities.

Recommendations for strategic management of sustainable food production in Ukraine

To develop an effective strategy for sustainable food production in Ukraine, it is necessary to define the areas in which international experience can be tailored to national realities, as this approach will overcome existing technological, institutional and social barriers. A key element of the modernisation of the domestic agricultural sector should be large-scale digitalisation and the introduction of modern technological solutions, using Kenya's successful practice of expanding digital services and specialised agricultural applications as a benchmark. In the Ukrainian context, the creation of similar mobile platforms and integrated management systems will provide small and medium-sized farmers with rapid access to market data, weather forecasts and expert advice, which will significantly increase the efficiency of resource use and the transparency of all value chains.

The practical implementation of the digital twin concept in conditions of active hostilities and budgetary constraints in Ukraine should be based on the principles of lean innovation and the use of open-access data. Instead of creating expensive closed systems, it is advisable to use the synergy of free satellite images from the Sentinel-2 (Copernicus) programme and open-source machine learning algorithms to automatically detect funnel formations and chemical burns on the soil. This approach provides initial monitoring of land conditions without the need for expensive manned aviation or commercial space services. The logistical implementation model requires the creation of a two-tier data structure: the first tier is formed through crowdsourced mobile platforms, where farmers and representatives of local communities independently record the coordinates of damage, and the second tier involves automated verification of this data by state authorities through integration with the Land Cadastre. This transforms the digital model into a dynamic risk management tool that prioritises demining and recultivation costs only in those areas with the highest potential for restoring fertility, ensuring maximum economic efficiency of every hryvnia invested in conditions of martial law.

Within the framework of strategic management, social components and the development of inclusive economic models that have proven their viability on a global scale are noteworthy. The model of the Indian association SEWA and the experience of organic coffee cooperatives in Costa Rica and other Central American countries should become the foundation for developing mechanisms to support farmers' cooperatives, particularly women's cooperatives, in Ukraine. The implementation of such approaches will not only contribute to improved financial stability of rural communities through shared access to markets and modern processing technologies, but will also ensure self-employment among the population and increase food security at the local level. Institutional strengthening of Ukrainian sustainable development policy requires the systematic implementation of educational programmes aimed at disseminating knowledge about environmentally friendly production methods. It is advisable to consolidate initiatives at the state level, following the example of FAO Farmer Field Schools, which have proven their effectiveness in transferring practical experience in regenerative agriculture and biological plant protection. The creation of a network of regional knowledge transfer centres in Ukraine will ensure adaptation of farmers to climate change and implement sustainable management principles directly into the production process, which is critical for maintaining soil fertility in the long term.

Further refinement of the strategy requires a profound transformation of political and economic incentives, which must correlate with measures implemented in the European Union and India. For Ukraine, it is necessary to move away from traditional models of direct subsidies towards flexible economic instruments that encourage compliance with ESG standards and the achievement of Sustainable Development Goals. This involves the introduction of a system of "green" payments for the application of environmental practices, expanding access to preferential lending for high-value-added projects, and creating a favourable investment climate for low-carbon technologies. The proposed set of measures justifies the key areas for improving Ukraine's sustainable agricultural production policy, demonstrating its high potential in the context of global trends. Combining the innovative digital experience of developing countries with the systematic regulatory mechanisms of developed economies will transform Ukraine's agricultural sector into a high-tech and socially responsible industry. Such an integrated approach will not only increase the competitiveness of domestic products on world markets but also form a sustainable production model capable of effectively countering modern geopolitical and climatic challenges.

DISCUSSION

The results of the study are consistent with trends that emphasise the need for a balance between economic efficiency, environmental sustainability and social inclusiveness. The results indicate a direct correlation between short-term planning and resource degradation, confirming the hypothesis that sustainable food production requires not just technological upgrades, but fundamental changes in strategic management. This phenomenon is a consequence of path dependency, where strategic decisions continue to follow outdated, intensive models despite obvious environmental and economic losses. This conclusion is partially confirmed by R. Chand (2022), highlighting the need for a transformational vision for the agricultural sector. However, this study enters into a key debate with this approach and argues that vision alone is not enough: it must be backed by institutional power and inter-agency coordination. The analysis shows that economic pressure on productivity dominates environmental sustainability if it is not restrained by mandatory KPI monitoring and transparent accountability. The critical role of key performance indicators (KPIs) was addressed by J. Schokker *et al*. (2022), justifying the implementation of climate risk indicators. This study does not deny the need for KPIs, but questions their universality and the effectiveness of implementation.

Systemic failures in monitoring, highlighted in the MOPAN (2024) assessment of food organisations, are a more critical barrier to sustainability than the choice of specific KPIs. Low transparency effectively devalues even the best KPIs. Research data from M.W. Jordon *et al*. (2022) and A.M. Prairie *et al*. (2023) confirm that the implementation of integrated CSA systems not only preserves but also increases organic carbon stocks in the soil, creating the conditions for the development of carbon neutrality strategies in agriculture. CSP changes strategic management at the sector level, transforming it from a simple production system to an ecosystem service. This requires governments to develop policies that encourage carbon sequestration and create carbon markets where farmers can monetise environmental benefits, ensuring that environmental sustainability becomes a financially attractive strategy.

The case of Ukraine (72% of the budget for state programmes remains unused) is an indicator not only of institutional weakness, but also of high corruption risks and ineffective management. This institutional failure creates a favourable environment for the misuse of funds, which is a critical barrier to attracting international financing. The conclusion of the article reinforces the position of MOPAN (2024), transforming the requirement for transparency into a requirement for strict institutional accountability as the basis for sustainable development and overcoming institutional path dependency. M. Bastidas-Orrego *et al*. (2023) examined policy instruments for green infrastructure. This study reinforces this argument, emphasising that in crisis regions, investments must not only be "green" but also integrated into the national system of geopolitical and military risk management, ensuring the physical resilience of assets. This requires the development of unique instruments, such as Sovereign War Risk Guarantees, to stimulate private capital.

Strategic adaptation is another significant point of discussion. The concept of localising strategies resonates with the analysis of corporate sustainability strategies, particularly K. Tan (2025). However, it is necessary to distinguish between national and corporate strategies by proposing a Hybrid Resilience Framework. This framework requires that national strategies be differentiated by region and include adaptation to geopolitical threats that go beyond traditional risk management. Traditional, linear scenario planning (regarding climate or the market) has proven ineffective in the context of geopolitical challenges, such as full-scale invasion, which requires a dynamic rebalancing between export-oriented and domestically oriented production models.

Y.-Y. Shih *et al*. (2025) on restructuring global supply chains through the "China-plus-one" strategy (pull-push-lock) is valuable. However, a more complex strategic challenge emerges in the Ukrainian context: the country must maintain key export markets while ensuring domestic food security, which requires the implementation of a hybrid strategy of localisation and global integration, as opposed to simple supply chain diversification. For agribusiness as a whole, the importance of scenario planning for climate disaster resilience is emphasised. This need must be expanded by requiring the integration of military risk scenario planning (destruction of logistics, mining of territories) into any long-term agricultural strategy. This includes not only risk assessment, but also planning for the rapid replacement of critical infrastructure (e.g., mobile grain elevators). Furthermore, it is proposed that the strategy include government mechanisms for insuring military risks and targeted funding programmes for demining and restoration, making investments in resilience physically secure. Innovative solutions such as controlled environment agriculture (CEA) demonstrate the potential to increase productivity by up to 300%. The analysis argues that in the context of post-conflict recovery, CEA is not just a technological improvement but a strategic necessity for the rapid and safe restoration of production in damaged areas.

The issue of energy sustainability is also critical. Concerning the circular economy, the conclusions of M. Fazle Rabbi & M. Bin Amin (2024) on the role of AI and blockchain in increasing transparency and optimising supply chains are indisputable. The contribution of the study consists of an analysis of the use of these tools for rapid environmental restoration, in particular for monitoring and decontaminating degraded soils. To finance sustainability in high-risk conditions, it is necessary to move away from traditional lending models. Blended finance, which combines concessional public capital or guarantees with private investment, should be the key mechanism. This should be accompanied by the issuance of Targeted Green Bonds, the proceeds of which are strictly directed towards soil restoration projects and the implementation of low-carbon technologies.

While emphasising the technological potential of CEA, the sustainability strategy cannot ignore social justice. Without inclusive financial mechanisms for small and medium-sized farms, the introduction of high-tech solutions (CEA, AI) will only exacerbate regional and social inequalities. It is necessary to create decentralised innovation hubs that facilitate the transfer of knowledge and technology. This requires the development of Green Skills among workers and managers, as well as the development of a new training and certification system that meets the requirements of a high-tech and sustainable agricultural sector. This study emphasises general trends and proposes the introduction of a national concept of a "digital twin" for the agricultural sector. This tool can be used by government agencies and investors to conduct scenario modelling of the impact of strategic decisions (e.g., subsidising specific technologies) on sustainability (organic carbon growth) and national security. It transforms management from reactive to predictive, which is critical in conditions of high uncertainty. In addition, it provides uncompromising transparency for international partners, minimising corruption risks and facilitating capital attraction. This concept involves creation of a virtual, dynamic model of all key agricultural resources and infrastructure, combining: This model comprehensively combines Geospatial Data (soil condition, including organic carbon and pollution, mining data, water resource monitoring), Production Indicators (actual yield, resource consumption, energy efficiency, according to J. Schokker *et al*. (2022) and Logistics Networks (dynamic supply chain models, optimised to account for military risks and Hybrid Resilience).

Thus, the study complements existing literature by integrating aspects of sustainability with a critical analysis of geopolitical and military risk. The introduction of the concept of institutional dependence explains resilience to change, while the hybrid resilience framework offers a mechanism for adapting to multidimensional crises. It is necessary to shift the focus from technological optimisation to institutional efficiency, financial innovation and digital transparency (through digital twins), which is a fundamentally new approach for countries facing permanent crisis challenges. The conclusion is that food security is, first and foremost, a strategy for national security, institutional resilience and social inclusion, and only then for environmental and economic efficiency.

CONCLUSIONS

Based on an in-depth analysis of sustainable food production principles and strategic management mechanisms, the study confirms that ensuring sustainability is a systemic challenge that requires the integration of economic, environmental and social mechanisms. The study established that progressive technologies (precision farming, regenerative agriculture, and blockchain) create the necessary potential for sustainable food production. At the same time, strategic management must be transformed from a set of separate policies into a dynamic process of multi-level governance and integrated risk management (climatic, geopolitical).

An analysis of successful and unsuccessful cases has revealed critical conditions for effective food system management. First, this requires a systematic approach with clear inter-agency coordination and integration of innovations. It also requires the localisation of strategies that take into account the local context, infrastructure and cultural characteristics. A key element is KPI-based assessment, which can be used for real-time management of results and policy adjustments (e.g. through monitoring of carbon footprint and food security index). At the same time, short-term planning, lack of transparent monitoring and corruption risks remain critical barriers. The study determined that achieving sustainability is context-dependent: in developed countries, it is achieved through technological advantage and institutional maturity, while in developing countries, it is achieved through social mobilisation and a focus on affordable agroecological solutions. Failures in strategic management lead to significant quantitative losses. The consequences of export-oriented strategies are reflected in increased CO emissions, which undermine international climate commitments. The low effectiveness of financial strategies to support farming is a direct indicator of weak monitoring and corruption risks. In contrast, targeted, KPI-oriented strategies demonstrate high potential: innovative case studies confirm a 90% reduction in water consumption and a 300% increase in productivity. Management models focused on climate KPIs ensure the achievement of CO_2 emission reduction targets of 35% and the successful restoration of degraded land.

The implementation of strategic management of sustainable food production in Ukraine should integrate innovations into financial and educational mechanisms. It is recommended to develop comprehensive sustainable development strategies with a horizon of 10-30 years, introduce transparent financing mechanisms, and support sustainable technologies and adaptation measures. The combination of targeted investments, subsidies and inter-agency cooperation yields positive results. Further research should focus on developing models of climate and economic change scenarios for Ukraine's agricultural sector. This requires the creation of KPI systems for assessing the environmental footprint and food security. It is necessary to explore the potential of AI, biotechnology and circular economy models as strategic resources for post-conflict recovery, as well as to study mechanisms for scaling up successful cooperative models and technology transfer for small and medium-sized farms.

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Стале виробництво продовольства та стратегічне управління: поглиблений аналіз

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Анотація. Метою дослідження стало проведення поглибленого аналізу принципів сталого виробництва продовольства, виявлення ключових викликів та розробка стратегічних рекомендацій щодо їх подолання в глобальному та регіональному контекстах України. Методологія дослідження базувалась на комплексному міждисциплінарному підході, що поєднує порівняльний, аналітичний і системний методи, які дозволяють всебічно оцінити екологічні, економічні та соціальні компоненти продовольчих систем у контексті сучасних глобальних викликів, тенденцій розвитку продовольчого сектору та впливу технологічних трансформацій. Здійснено поглиблений аналіз теоретичних основ сталого виробництва продовольства, досліджено державні та корпоративні стратегії управління продовольчими ресурсами, вивчено міжнародні ініціативи, програми співробітництва та інноваційні технологічні рішення, спрямовані на підвищення ефективності та сталості агропродовольчих систем. Встановлено, що ефективне стратегічне управління сприяє глибокій інтеграції екологічних, соціальних і економічних факторів у систем продовольчого виробництва, забезпечуючи збалансований розвиток аграрної сфери. Розроблено комплекс рекомендацій щодо адаптації міжнародного досвіду до умов України, зокрема у сфері розвитку агротехнологій, вдосконалення механізмів державного управління та підготовки висококваліфікованих кадрів для продовольчого сектору. Проаналізовано успішні кейси країн ЄС, США та Китаю, визначено їхні ефективні моделі реалізації сталих практик і можливості застосування цих підходів у вітчизняному контексті. Водночас виявлено, що недосконалість інституційних механізмів, обмеженість фінансових ресурсів і недостатня координація між державними та приватними структурами залишаються ключовими бар'єрами на шляху до сталості. Практична цінність дослідження полягає у можливості використання його результатів фахівцями у сфері стратегічного управління, державної політики та аграрного розвитку для підвищення ефективності національних програм продовольчої безпеки та досягнення Цілей сталого розвитку ООН

Ключові слова: сталий розвиток; інституційні механізми; адаптація до криз; глобальні виклики продовольчої системи; еколого-економічні відносини; відповідальне виробництво; інноваційний розвиток; природні ресурси