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Agri-food system as an object of strategic management: Conceptualisation and multi-level architecture

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▸ **Abstract.** The discrepancy between global food production volumes and the scale of chronic food insecurity indicates that the critical factors of agricultural sector resilience are formed beyond the level of an individual enterprise or market. Traditional analytical categories (industry, supply chain, agricultural market) do not take into account feedback loops between levels of aggregation and therefore fail to provide an adequate basis for strategic management. The purpose of this article was to substantiate the essence of the agri-food system as an integral multi-level object of strategic management, to identify its structural subsystems, and to demonstrate the role of information flows as a system-forming attribute. The methodological basis of the study comprised the systems approach, comparative analysis of theoretical frameworks (global value chain analysis, the HLPE/FAO systems approach, the multi-level perspective), and the method of theoretical synthesis. The frameworks were selected based on the criteria of the scale of analysis (linear-systemic), operational suitability for management, and coverage of feedback. An original definition of the agri-food system was proposed as a multi-level socio-technical configuration whose system-forming attribute is the organisation of feedback loops around the production, distribution, and consumption of food. Three structural subsystems (functional, institutional, and managerial) were identified, whose interaction is mediated by information flows. A four-level architecture of the agri-food system was developed as an analytical tool for strategic management. Indicators and an assessment scale were proposed for each of the five criteria of information-flow quality. Using the Ukrainian grain value chain as an example, the architecture's capacity to identify cascading inter-level contradictions was demonstrated, particularly between macro-level regulatory decisions and meso-level contractual obligations. The results can be used in developing national strategies for agri-food system development in the context of European integration. The proposed information flow assessment scale serves as a diagnostic tool for agricultural policy authorities and industry associations

▸ **Keywords:** information flows; value chains; institutional environment; digital transformation; food security; coordination mechanisms

▸ Introduction

Even during periods when global food production exceeded the nutritional needs of the population, a significant proportion of people continued to experience chronic food insecurity. This persistent paradox suggests that the decisive factors of agricultural sector resilience are formed beyond the boundaries of an individual enterprise or market. This explanatory insufficiency of traditional approaches has led to the gradual consolidation of the category "agri-food system" in the management discourse.

At the same time, the theoretical status of this category remains undefined. The sectoral approach constructs its object as a set of producers with similar product functions. The market approach focuses on the price mechanism of demand-supply coordination. The supply chain describes a sequence of technologically linked operations. None of these analytical frameworks fundamentally account for feedback loops between levels of aggregation. For instance, shifts in consumer preferences can transform production standards, while regulatory decisions can restructure market architecture. Consequently, these approaches fail to capture systemic non-linearity, whereby the outcome cannot be derived from the sum of local

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decisions. In Ukrainian scholarship, this conceptual shift towards a systemic vision was registered by O. Varchenko (2023), who substantiated the structure of the agri-food system as an integral configuration of production, processing, distribution, and consumption. The author emphasised the functional interconnections among these components; the operationalisation of the agri-food system as an object of strategic management, however, remains an open question.

Processes that are fundamental to the sector's development unfold at the systemic level. These include the formation of quality standards, concentration of bargaining power, cross-chain technology diffusion, institutional regulation of land turnover, and cross-sectoral diffusion of digital technologies. The cost of ignoring this systemic dimension became evident in the context of the digital transition, which is a restructuring phenomenon extending far beyond the technical optimisation of individual operations. A report by the European Commission (2025) documented that agricultural research had long concentrated at the enterprise level, whilst coordination mechanisms, the quality of the institutional environment, and knowledge diffusion among system participants remained outside the scope of operational analysis. This research gap carries a specific managerial cost, which is reproduced in the gap between available technological solutions and their actual adoption at the sectoral level.

The research on agri-food systems unfolds along several thematic lines that converge at the systemic level of analysis. The FAO Strategic Framework for 2022-2031 (FAO, 2021) anchored the agri-food system as a central operational category and identified four "accelerators" of systemic transformation: technology, innovation, data, and a set of institutional complements (governance, human capital, institutions). At the same time, the document articulates normative goals rather than a theory of managerial mechanisms, leaving open the question of how systemic transformation is actually to be achieved. A systematic review by F. Elsner *et al.* (2023) brought together 58 studies that applied the multi-level perspective (MLP) to sustainability transitions in agri-food systems over 2018-2022. The authors registered the broad uptake of the MLP as an analytical instrument; methodological heterogeneity and the predominantly qualitative character of these analyses, however, constrain its transfer to the tasks of normative-managerial design.

S. Rolandi *et al.* (2021) proposed a taxonomy of the impacts of agricultural digitalisation. Their analysis identifies both positive effects, such as productivity gains and the opening of new markets, and risks of a digital divide and uneven territorial impacts. This points to the reconfiguring rather than uniformly improving character of digital transformation. The OECD (2022) policy review systematized the literature on agricultural digitalisation and the emerging policy questions it raises. The authors note that the diffusion of digital technologies in agriculture is constrained by a combination of economic, technical, and institutional factors. Among these, institutional barriers play a particularly visible role, including problems of data governance, the incompleteness of standards, deficits of trust, and an underdeveloped regulatory environment. Overcoming such constraints calls for coordinated regulatory and educational interventions.

In the Ukrainian context, I. Yanenkova (2022) established that an unfavourable institutional environment substantially hampers modernisation processes. The decisive barrier was identified as the absence of adequate legal institutions and procedures for the protection of property rights. S. Ibatullin *et al.* (2024) analysed the challenges of agricultural land market liberalisation in Ukraine and the directions of subsequent reform. The authors identified the uncertainty surrounding the rights of buyers and sellers of land, errors in the data of the state land cadastre and the registry of real rights, and the risks of ownership concentration by large agricultural structures as the principal constraints on transparent land turnover. These constraints carry direct consequences for the institutional configuration of the sector. Yu. Lopatynskyi *et al.* (2024), drawing on a sample of small agricultural enterprises operating under wartime conditions, showed that adaptive capacity is above all an organisational quality. It manifests as the ability to rapidly reconfigure internal subsystems, to self-organise, and to generate innovative responses to institutional change. Among the key external barriers, the researchers singled out the inefficiency of state regulatory mechanisms and legal instability.

J.E. Hobbs (2020), drawing on the COVID-19 shock as empirical material, showed that decisions of individual chain participants, although rational from the standpoint of their own resilience, in fact generate systemic disruptions through panic effects and cascading reactions. The finding underscores that the management of food chains under stress calls for a systemic rather than a firm-level perspective. E. Curtis *et al.* (2024) quantified the cascading impact of the war on Ukraine's grain sector. The authors documented losses exceeding USD 80 billion and reductions in the area under wheat, maize, and barley of 32%, 27%, and 37% respectively. This serves as an illustration of how supranational-level shocks propagate downwards through every lower level of the agri-food architecture.

The approaches reviewed above draw on a broad empirical base. Yet none of them offers an operational managerial apparatus for the targeted transformation of agri-food systems. The question of how to move from concrete starting positions to a desired strategic state remains methodologically unaddressed. The literature converges on identifying the institutional environment as a critical determinant, yet it stops short of constructing a multi-level managerial architecture in which information flows would function as the system-forming attribute.

The purpose of this article was to substantiate the essence of the agri-food system as an integral multi-level object of strategic management, to identify its structural subsystems, and to demonstrate that information flows constitute a system-forming attribute, without which strategic management of the agri-food system remains declarative.

▸ Materials and methods

The aim of the study was pursued through a complex of theoretical methods for processing information. Systems analysis made it possible to treat the agri-food system as an integral configuration with non-linear feedback loops between its subsystems. Comparative analysis was used to

set the three theoretical frameworks Global Value Chains (GVC), the High Level Panel of Experts on Food Security and Nutrition/Food and Agriculture Organisation (HLPE/FAO), and the MLP against the selection criteria, whilst critical synthesis enabled the extraction of analytical categories from each framework and their integration into a single conceptual construct. Conceptual modelling was deployed to build the author's model of structural subsystems and the four-level architecture of the agri-food system. Abductive reasoning was applied to derive the framework-selection criteria from the substance of the research aim, and content analysis served to process the programme documents of international organisations and a body of analytical reports. The information-processing procedure was carried out sequentially. To begin with, analytical categories were extracted from each framework and tabulated comparatively against the selection criteria. The selected categories were then integrated into a synthetic construct. At the final stage, the resulting architecture was subjected to an illustrative application to the Ukrainian grain value chain.

The methodological basis of the study was the systems approach, which entails examining the agri-food system as an integral configuration of interdependent elements with non-linear feedback loops. This approach made it possible to overcome the limitations of sectoral and chain-based analysis, which reduce complex inter-agent configurations to linear sequences. The systemic perspective shifted the focus from individual participants to the links between them and to the coordination mechanisms that ensure the integrity of the configuration. The selection of theoretical frameworks for comparison followed a clear procedure that warrants separate explanation. At the first stage, an extended list of approaches claiming to provide a systemic understanding of inter-firm and cross-sectoral configurations in the agricultural sector was compiled. In addition to the three selected frameworks, the world-systems theory of I. Wallerstein, the actor-network theory of B. Latour, and the social-ecological systems concept of E. Ostrom were also considered. At the second stage, each approach was assessed against three criteria directly derived from the research objective.

The first criterion was analytical scope. The assessment examined whether the framework is capable of simultaneously addressing the micro, meso, and macro levels of the agri-food system while capturing the feedback loops between them. The second criterion was the availability of an operational managerial apparatus, that is, whether the framework offers categories that can be directly translated into the domain of strategic decisions. The third criterion was suitability for the context of systemic transformation, particularly for post-transformation economies with substantial institutional uncertainty. World-systems theory was rejected due to its predominant orientation towards the global level of analysis, with limited attention to intra-system coordination mechanisms. Actor-network theory, despite its powerful analytical apparatus for describing heterogeneous networks, proved excessively constrained for the tasks of strategic management. Its principled agnosticism regarding hierarchies complicates the identification of levels of managerial decisions. The social-ecological systems concept focuses primarily on ecological resilience and common resource management, which makes it less suitable specifically for the managerial dimension of agri-food issues. It should be noted that this selection does not constitute an assessment of the overall scholarly value of these approaches. They addressed different research tasks and may prove productive for other aspects of agri-food issues.

As a result, three frameworks were selected for comparative analysis: global value chain analysis (Gereffi *et al.*, 2005), the HLPE/FAO systems approach (HLPE, 2017), and the MLP of F.W. Geels (2002). Each of these satisfies at least two of the three criteria while possessing specific limitations, which justifies the need for a synthetic approach. The comparison was aimed at identifying the analytical capabilities and methodological limitations of each framework with regard to the strategic management of agri-food systems.

The method of theoretical synthesis was applied to construct the author's model of structural subsystems and the four-level architecture of the agri-food system. The synthesis procedure involved extracting from each framework those analytical categories that satisfy all three selection criteria, followed by their integration into a unified conceptual construct. Transaction cost theory (Williamson, 1979) was employed for the analysis of coordination mechanisms. The resource-based view (Barney, 1991), the dynamic capabilities concept (Teece *et al.*, 1997), and the five forces model (Porter, 1998) were analysed as theoretical traditions of strategic management that require adaptation for the systemic level of analysis.

The information base of the study comprised the programme documents of the FAO (FAO, 2021; FAO, 2023), the analytical materials of the European Commission (2025), and those of the Organisation for Economic Co-operation and Development (OECD, 2022). Priority was given to sources containing empirical data or proposing verified analytical frames.

▸ Results and discussion

The first analytical tools for studying transnational agri-food networks emerged in the 1990s amid discussions on the restructuring of global production. G. Gereffi (2018) showed that in a number of industries, the leading agents of coordination are not those who control production capacities but rather those who control access to the end market. Large retail chains and brand owners set the standards, assortment, and delivery terms for thousands of producers without owning them. For the agricultural sector, this logic proved no less relevant than for textiles or footwear, on which it was initially developed. Large-scale retail and processors replicate the model of coordination without ownership, albeit with a different subject matter and greater dependence on seasonal and natural factors.

The typology of governance forms for global value chains, proposed by G. Gereffi *et al.* (2005), shifted the focus from the question "who controls the assets?" to "by what logic do firms choose between market and hierar- chy?". The coordination regime of a chain depends on the informational complexity of transactions, the degree of their standardisation, and the supplier's capacity to meet standardised requirements independently. Different combinations of these dimensions generate

qualitatively different coordination regimes. These extend from anonymous market transactions to full vertical integration, including three intermediate forms: modular, relational, and captive coordination. For the agricultural sector, this differentiation is essential, as each form of coordination requires a different level of institutional support and information infrastructure. The coordination regime is not fixed; it shifts in tandem with changes in informational complexity.

L. Dries *et al.* (2004) documented that the "supermarket revolution" in Central and Eastern European countries was accompanied by large-scale vertical coordination. Major retail chains introduced private quality standards, transitioned from spot markets to centralised procurement systems, and established long-term contractual relationships with suppliers. Applying the typology of G. Gereffi *et al.* (2005), these transformations can be interpreted as a shift of the region's agri-food chains towards captive or relational coordination regimes, depending on the supplier's level of competence and the degree of power asymmetry. These shifts coincided with the diffusion of quality control and traceability technologies. The coincidence is not accidental. The demand for verified quality generates demand for technology, and technology in turn becomes a new barrier to entry, altering the balance of power within the chain.

GVC analysis successfully identifies such mechanisms, yet it has a fundamental limitation embedded in the very logic of the chain-based approach. The GVC perspective makes it possible to describe the producer's vulnerable position in a chain where contract terms, quality requirements, and payment schedules are effectively dictated from links to which the producer has neither access nor influence. At the same time, the chain as a unit of analysis by design does not capture horizontal interactions between different chains, nor does it capture the ecosystem consequences of agri-food activities. The toolkit, refined on examples such as electronics and textiles, has revealed limitations when transferred to the agricultural sector, owing to the seasonality of operational cycles, the nature-dependent character of production outcomes, and the specific nature of land resource management.

O.E. Williamson's (1979) transaction cost theory opens an additional dimension for understanding coordination mechanisms. Under conditions of incomplete specification of property rights, transaction costs assume forms that substantially exceed ordinary negotiation costs. These include costs of contract enforcement, protection against opportunistic behaviour of partners, and quality verification in the absence of reliable certification systems. Transaction costs constitute a substantial yet often unidentified element of an enterprise's cost structure (Kniaz *et al.*, 2025). At the macro level, T.V. Herasymenko (2021) documented that since 2019, the growth rate of the transaction sector in the Ukrainian economy has substantially outpaced the growth of transformation costs, indicating systemic institutional inefficiency. Digital technologies of traceability and smart contracts are theoretically capable of reducing these costs. However, this potential is realised only in the presence of a minimum level of legal certainty. Technology can reduce verification costs but cannot substitute for the basic infrastructure of contract law.

In parallel with the development of GVC analysis, another scholarly stream was forming, moving from the chain to the system, primarily within the fields of food geography and ecological economics. J. Ingram (2011) argued that food security research requires a systemic framework in which production practices, market structures, dietary behaviour, and environmental consequences are examined in their inseparable interrelation. The fundamental distinction from the chain-based approach lies in the recognition of feedback loops as a constitutive feature of the system. New production technologies alter the structure of demand. Demand generates new quality requirements. These requirements influence the investment decisions of producers, which in turn transform the technological landscape of the sector. Technology in this context does not merely replace a manual operation; it restructures the configuration of information flows and power relations within the system as a whole. It is precisely this chain-like nature of feedback loops that transforms any technological change into a strategic task extending far beyond a purely technical solution.

The conceptual synthesis that combined the achievements of chain analysis and systems thinking was the 2017 report of the High Level Panel of Experts on Food Security and Nutrition at the FAO Committee on World Food Security (HLPE, 2017). Its contribution lies not in the enumeration of food system components but in how these components are interconnected. The document proposed an analytical framework in which food supply chains, the food environment, and consumer behaviour are examined as interdependent elements of a single configuration. The report identified the "food environment" as an independent analytical level between supply and consumer behaviour. At this level, actual access to food is determined not by production volumes but by price affordability, physical infrastructure, and socio-cultural norms. This interpretation is fundamentally broader than the chain-based approach, as it incorporates the environment as an integral structural element – specifically, the physical, economic, political, and socio-cultural context in which consumers interact with the food system.

A comparison of the reviewed approaches provides grounds for the following definition. The agri-food system is a multi-level socio-technical configuration that unites interrelated agents (producers, processors, distributors, consumers, regulators, knowledge providers), formal institutions, technologies, and the natural-resource conditions of their activities. The system-forming attribute is not the composition of elements per se but the organisation of feedback loops between them around the production, distribution, and consumption of food. It is precisely the feedback loops that transform a collection of agents and rules into an integral system, where a change in one component inevitably triggers cascading reactions in others. Equating the agri-food system with an "industry", a "market", or a "supply chain" is a methodological error, as these categories by design do not account for feedback loops between levels of aggregation. The proposed definition enables a transition to the internal structure of the agri-food system. On the basis of the reviewed theoretical approaches, three structural subsystems can be identified as operational units of strategic management (Table 1).

Table 1. Structural subsystems of the agri-food system and their managerial role

Subsystem	Key elements	Managerial role	Status indicators
Functional	Production, processing, logistics, retail, consumption	Object of technological modernisation	Productivity (t/ha), losses at logistics stages (%), share of value added accruing to the producer
Institutional	Legal norms, quality and safety standards, Agricultural Knowledge and Innovation System (AKIS), land relations	Determinant of functional subsystem efficiency	Property rights protection index, contract enforcement rate (%), extension services coverage (% of farmers), share of transaction costs in production cost
Managerial	Corporate strategies, agricultural policy, EU/FAO regulations	Mechanism for targeted systemic transformation	Existence of strategic documents, planning horizon (years), share of budget for development and support, degree of harmonisation with the acquis communautaire

Source: compiled by the author

The functional subsystem encompasses the set of activities that form the "core" of the system: agricultural production, processing and storage, distribution and logistics, retail trade, and food services. This subsystem is most frequently equated with the agri-food system as a whole. Such simplification is a methodological error with specific managerial consequences, as the subject of strategic management is narrowed to the technical modernisation of individual links. The efficiency of the functional subsystem is decisively determined not by its internal organisation but by the quality of the other two subsystems.

Why do technologically sound decisions in the agricultural sector frequently produce outcomes opposite to those expected? To a large extent, this is due to the state of the institutional subsystem, which comprises the formal and informal rules of interaction between agents. It includes regulatory and contract law, quality and safety standards, land relations, and the advisory and research-educational infrastructure (AKIS). In the Ukrainian context, this subsystem remains the bottleneck – not because of a shortage of normative acts (which are sufficient), but because of a chronic gap between formal rules and the actual practices of their application. I. Yanenkova (2022) established that an unfavourable institutional environment substantially hampers modernisation processes. The absence of adequate legal institutions and procedures for the protection of property rights constitutes a determining barrier. M. Odnorog *et al.* (2019) confirmed that it is precisely ineffective institutions in the agricultural sector that reduce the reliability of property rights protection, undermine contract enforcement, and generate opacity. Institutional inefficiency in the Ukrainian agri-food sector takes on a number of concrete forms. The turnover of agricultural land is marked by errors in the data of the state cadastre and the registry of real rights, as well as by the uncertain status of the rights of parties to transactions (Ibatullin *et al.*, 2024). Transaction costs make up a substantial yet often unidentified component of the cost structure of agri-food production (Kniaz *et al.*, 2025). A pronounced asymmetry also persists in access to market and regulatory services between large agricultural structures and small producers (Lopatynskyi *et al.*, 2024). Without an adequate institutional configuration, technological transformation does not overcome existing asymmetries between large- and small-scale producers but rather entrenches them.

If the institutional subsystem defines the "rules of the game", then the managerial subsystem defines the system's capacity for targeted transformation. It encompasses the mechanisms of goal-setting, coordination, and strategic planning at all levels of aggregation, extending from the corporate strategies of agricultural holdings to the state's agricultural policy and the normative frameworks of the EU and FAO. The boundary between the institutional and managerial subsystems is not always clear, as agricultural policy simultaneously shapes the institutional environment and serves as a managerial instrument. One illustration is the phased opening of the agricultural land market in Ukraine from 2021 onwards. This reform simultaneously reshaped the institutional environment by introducing the right to trade share-distributed land and operated as a managerial instrument in its own right. Its managerial dimension was realised through the segmentation of the circle of eligible buyers, caps on the volume of ownership, and the sequencing of liberalisation phases (Ibatullin *et al.*, 2024). This imprecision is not a flaw of the classification but a reflection of the actual complexity of the object.

Non-linear relationships with reciprocal influence exist between the subsystems. Technological shifts in the functional subsystem generate pressure for the reformatting of the institutional subsystem. For instance, the proliferation of agricultural data and platform-based solutions creates demand for new legal norms regarding data ownership. At the same time, changes in the managerial subsystem determine the character and pace of technological transitions. Hence the methodological necessity of a systems approach to strategic management.

Information flows serve as the connective link between the three subsystems. Without them, the functional subsystem operates "blindly": the producer lacks data on actual demand, the processor receives no feedback from retail, and the consumer is deprived of information about the origin and quality of the product. In the institutional subsystem, information flows underpin the operation of standards, certification, traceability, and the functioning of advisory services. In the managerial subsystem, it is on the basis of information flows that decisions of varying scope are formed – from operational (daily inventory management) to strategic (choice of development paths, formation of agricultural policy). A strategic decision made without reliable information flows becomes an intuitive decision with an unpredictable outcome.

O. Honcharenko *et al.* (2019) established that the key factors of innovation development in agricultural production are not only the financial-resource base of enterprises but, above all, the totality of institutional determinants – formal and informal rules, norms, and incentives

that shape the space of possibilities for innovative activity. Yu. Lopatynskyi *et al.* (2024) demonstrated that the adaptive capacity of small agricultural enterprises is a function of the quality of the institutional environment rather than of the level of their technical equipment. Among the key institutional barriers, the researchers identify the inefficiency of state regulatory mechanisms, legal instability, and insufficient support from government and local self-governance bodies. Within the Ukrainian agri-food sector, the inefficiency of regulatory mechanisms takes on several characteristic forms. The data held in the state land cadastre and the registry of real rights contain numerous errors and inaccuracies (Ibatullin *et al.*, 2024), which lowers both the transparency of land turnover and the quality of analytical information available to market participants. This confirms the proposition that the effectiveness of information flows in the agri-food system is determined not so much by the technical characteristics of transmission channels as by the institutional environment in which they operate. An integral component of institutional maturity is human capital, the deficit of which in rural areas constitutes a structural constraint on the modernisation of the agricultural sector.

Information flows perform a system-forming function. They are a constitutive element without which the three subsystems do not form an integral agri-food system but remain disparate sectors. The quality of information flows thus becomes the primary subject of strategic management. Declaring information flows as a system-forming attribute requires operationalisation, without which this thesis remains rhetorical. The quality of an information flow in the agri-food system can be assessed against five criteria, for each of which indicators and an ordinal assessment scale were proposed below (Table 2).

Table 2. Operationalisation of information flow quality criteria in the agri-food system

Criterion	Content	Indicators	Assessment scale (1-5)
Completeness	Whether the flow covers all levels of aggregation or breaks off at a certain point	Number of levels reached by the market signal; share of producers receiving information about the final price	1 – signal does not extend beyond a single level; 5 – end-to-end flow from producer to supranational regulator
Timeliness	Interval between signal generation and its receipt by the addressee	Lag (in days/weeks) between a market price change and the producer's response; speed of data updates in information systems	1 – lag of 1-2 production cycles; 3 – weekly updates; 5 – real-time mode
Bidirectionality	Existence of feedback from lower to higher levels	Existence of mechanisms for aggregating data from farmers to the regulator; share of producers covered by consumer feedback	1 – unidirectional top-down flow; 3 – fragmented feedback; 5 – systematic bidirectional communication
Accessibility	Openness of information to all participants rather than monopolisation by individual players	Share of value chain participants with access to market information; cost of access to information services relative to producer income	1 – information available only to dominant players; 3 – partial openness through public registries; 5 – equal access through open platforms
Institutional embeddedness	The extent to which the flow is supported by standards, protocols, and legal norms	Existence of data exchange standards; legal regulation of traceability; level of digital integration of extension services	1 – absence of formal standards; 3 – standards exist but are partially enforced; 5 – full institutionalisation with effective enforcement

Source: compiled by the author

The proposed scale is ordinal and at this stage of the research deliberately does not claim interval measurement precision. The difficulty lies in the fact that most indicators require the collection of primary data that are either absent in domestic statistics or recorded with a substantial lag. The operationalisation proposed in Table 2 is therefore a first step towards measurement rather than a completed metric. At the same time, even an ordinal assessment enables the comparison of information flow conditions across different chains and the identification of those criteria where the gap is greatest. In traditional agri-food systems, the market signal frequently reaches the producer with a delay of one to two production cycles, rendering timely adaptation impossible. The absence of even one of the five criteria transforms an "information flow" into "information noise", incapable of supporting sound strategic decisions. The identification of structural subsystems describes the "horizontal" cross-section of the agri-food system. The "vertical" cross-section is no less essential. At each level of aggregation, qualitatively different coordination mechanisms and managerial logics operate. The transition from a chain-based to a system-based unit of analysis has direct managerial implications, as it extends strategic management beyond the boundaries of an individual enterprise.

Three theoretical traditions of strategic management share a common methodological assumption that is simultaneously their fundamental limitation. J. Barney (1991) argued that sustained competitive advantage is formed on the basis of resources that are valuable, rare, difficult to imitate, and non-substitutable. The unit that accumulates them, in his concept, is the enterprise. D.J. Teece *et al.* (1997) shifted the emphasis from existing resources to the firm's capacity to integrate and transform its competences under conditions of technological change – but again within the firm-level analysis. M.E. Porter (1998), by focusing on industry positioning, came closer to a systemic view than the others; however, in his framework the industry remains an external environment rather than an object of management. It is precisely this shared enterprise-level orientation that constitutes the methodological threshold that must be overcome when transferring the strategic

management apparatus to the agri-food system level. To overcome this limitation, a multi-level architecture that extends beyond the firm level of analysis is proposed.

The analysis presented above justified a four-level architecture of the agri-food system that simultaneously accounts for the managerial and analytical dimensions (Fig. 1). This architecture is a theoretical construct developed specifically for the needs of managerial (and not merely analytical) application. The number of identified levels is not arbitrary but is determined by qualitative differences in coordination mechanisms and types of managerial decisions.

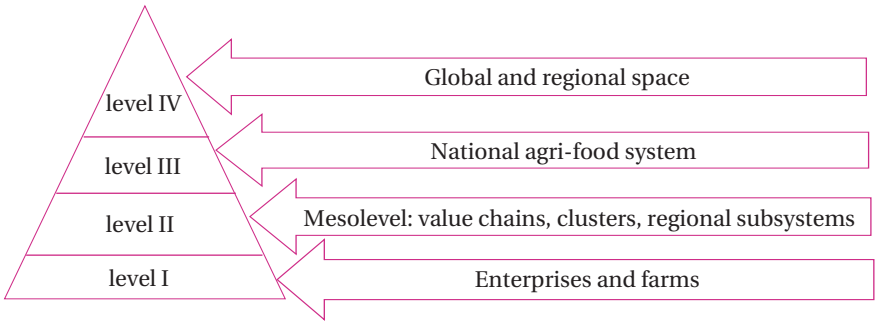

Figure 1. Four-level architecture of the agri-food system
Source: compiled by the author

The micro-economic level I encompasses agents that directly make production and commercial decisions – from large agricultural holdings to small households. As of 1 January 2024, the top 117 agricultural holdings in Ukraine cultivated 16% (6.45 million ha) of the country's agricultural land, operating exclusively on leased land (Ibatullin *et al.*, 2024). At the opposite pole are small households with a subsistence orientation of production. This polarisation defines the peculiarity of the micro level: a single coordination mechanism (market prices and intra-firm hierarchy) serves participants with fundamentally different resource bases and managerial competences. Large agricultural holdings maintain proprietary analytical platforms, data centres, and specialised staff, transforming technological modernisation into an instrument for reproducing competitive advantage. Strategic decisions at this level concern the choice of technologies, cost management, and diversification.

Coordination at the meso-economic level II operates according to a different logic. Contractual coordination, shared standards, and information platforms capable of ensuring data exchange between chain participants are required. Without such coordination, interaction is reduced to one-off transactions with substantial costs of verification and quality control. It is precisely at the meso level that global value chain theory revealed the uneven distribution of power. Buyers, processors, or retail chains are capable of shaping standards, access conditions, and the distribution of value added for all other participants (Reardon *et al.*, 2009). Such asymmetries can be observed at different levels of agri-food chains. In Ukraine's grain sector, this is reflected in the de facto setting of entry quality standards and payment terms for small producers by elevators and traders. A comparable pattern is visible in the retail segment of Central and Eastern European countries. Leading retail chains have built up a mechanism that segments producers' access to the consumer market through private quality standards and supply conditions. L. Dries *et al.* (2004) demonstrated that it was precisely this mechanism that determined the structural transformation of Central and Eastern European agri-food systems following liberalisation. In Ukraine, this tendency has specific manifestations, conditioned by the significant role of large agricultural holding structures (Keyzer *et al.*, 2013; Nizalov *et al.*, 2013).

A distinct mechanism of meso-level coordination is the cooperative form of organisation. Unlike vertically integrated agricultural holdings, cooperatives can open access to shared resources that are unattainable for individual small enterprises due to threshold effects of scale. International experience attests to the effectiveness of introducing digital traceability technologies on a cooperative basis, where a shared platform reduces quality verification costs for each individual participant. O. Budnik (2017) confirmed that cooperative marketing facilitates the development of small and medium-sized agribusiness. In Ukraine, however, the cooperative movement remains weak. As of 1 January 2025, 954 agricultural service cooperatives were registered in Ukraine (down from 1,039 a year earlier), yet only 327 of them were actually engaged in economic activity. Total founder membership stood at 3,270 persons (down from 3,857), averaging fewer than four members per registered cooperative (Ivchenko *et al.*, 2025). Such dynamics, in the context of wartime conditions, underline the critically low operational vitality of the cooperative sector.

The quality of the macro-economic level III is perhaps the most contentious issue for Ukraine. This level sets the regulatory regime and institutional configuration through land policy, agricultural insurance, the AKIS, and fiscal-credit mechanisms. M.A. Keyzer *et al.* (2013) found that the dualisation of Ukraine's agricultural sector – the coexistence of agricultural holdings and small subsistence households under conditions of weak market and advisory institutions – is not a temporary transitional state. What is at issue here is a specific form of institutional insufficiency. The market intermediation institutions that would serve small producers remain weak. Access to a high-quality advisory and knowledge infrastructure (AKIS) is limited. The institutions of shared use of market

assets, including elevators, technological lines, and logistical capacities, are underdeveloped. Such a configuration reproduces dualisation precisely because only large cardholding's command the internal resources needed to substitute their own infrastructure for the missing external institutions. This conclusion, drawn over a decade ago, retains its force. It is perhaps one of the most alarming indicators of the system's condition.

The functioning of Agricultural Knowledge and Innovation Systems is decisive precisely at the intersection of the second and third levels. Traditionally, AKIS encompasses advisory services, research institutions, and educational establishments that interact with farmers in the process of diffusing new technologies. At the same time, the digitalisation of AKIS itself remains a separate and still insufficiently explored area. Information flows at the macro level provide feedback between regulatory decisions and their actual impact on the system. The FAO Strategic Framework for 2022-2031 (FAO, 2021) orients all programmes towards systemic transformation through four "betters" (better production, better nutrition, better environment, better life), designating data and innovations as "accelerators" of transformation. Even this framework, however, answers the question "what?" and leaves the question "how?" open.

The supranational level IV acquires direct practical significance for Ukraine through the European integration course. It shapes external constraints and incentives through the EU, WTO, ISO, and Codex Alimentarius. European integration entails the gradual adoption of an externally imposed normative order, which requires large-scale restructuring of internal institutional configurations. D. Nizalov *et al.* (2013) demonstrated that under post-Soviet agricultural structures, productivity growth is determined not by economies of scale but by the quality of managerial and market institutions at the level of the individual farm and region.

These levels possess qualitatively different managerial logics. A decision that is rational at the enterprise level (for instance, forgoing costly certification to minimise costs) can be dysfunctional for the supply chain and pose risks to the system as a whole. J.E. Hobbs (2020) demonstrated, using the COVID shock as material, that decisions by individual chain participants – rational from the standpoint of their own resilience – generate systemic failures through panic effects and cascading reactions. T.V. Herasymenko's (2021) data on the accelerating growth of transaction costs in the Ukrainian economy relative to transformation costs provide grounds for the hypothesis that cost minimisation at the level of an individual agent, under conditions of a weak institutional environment, may paradoxically increase the transaction burden on the system as a whole. This effect is explained by the fact that savings on verification, quality control, or contract formalisation at the micro level generate additional costs of trust and coordination at the chain level. The temporal irreversibility of certain transformational transitions further complicates the managerial task, since erroneous strategic decisions at the systemic level are not amenable to simple correction.

Each transition between levels signifies a change in the type of coordination mechanism rather than merely a change in scale. At the micro level, coordination is effected predominantly through market prices and intra-firm hierarchy. The meso level requires contractual coordination, shared standards, and platform architectures. The macro level relies on the regulatory authority of the state and public programmes, whilst the supranational level ensures coordination through international agreements and voluntary standards. The difference in the type of coordination mechanism is precisely the criterion for identifying four levels. Information flows ensure connectivity between levels. Without them, each level functions autonomously, and the managerial decisions of one level fail to account for the constraints and opportunities of another.

These inter-level interactions are not neutral with respect to social outcomes. Their impact on the agri-food system is distributed unevenly. This is particularly evident at the level of food access, since even with a sufficient supply of quality products, actual access is determined by price affordability, consumer awareness, the physical accessibility of retail outlets, and socio-cultural consumption norms. S. Rolandi *et al.* (2021) demonstrated that agricultural sector modernisation has contradictory socio-economic effects. Increased productivity and the opening of new markets may be accompanied by the exclusion of certain social groups and regions with weak infrastructure. These effects are a manifestation of the non-linearity of feedback loops between levels. X. Li *et al.* (2021), on a sample of over a thousand small farmers in China, established that participants in agri-food e-commerce platforms receive substantially higher sales income. The effects, however, are heterogeneous depending on geographical location and the level of resource endowment of the household.

Information flows, identified as the system-forming attribute of the agri-food system, possess a further dimension directly linked to the practice of strategic management. Ensuring end-to-end information flows between all levels of aggregation is impossible under modern conditions without appropriate technological infrastructure. L. Klerkx *et al.* (2019) established that technological solutions are not adopted even where financial resources are available if the institutional infrastructure is absent. K. Kosior (2019) showed that the benefits of technological modernisation are distributed unevenly, and the market power of large agri-technology providers systematically constrains the transformation potential for smaller enterprises. The analysis of modernisation determinants conducted by the OECD (2022) and the JRC (European Commission, 2025) on a sample of 1,444 EU farms confirmed that enterprise size and ownership structure consistently rank among the primary factors of adoption.

The technological gap between large and small producers is deepened by the institutional incapacity of small farms – specifically, the lack of intangible assets, organisational competences, and access to contractual mechanisms (Reardon *et al.*, 2009; Klerkx *et al.*, 2019). The managerial implication is evident. Technological strategies must be developed inseparably from institutional ones. It is the quality of the institutional environment that primarily determines whether it enables technological transformation or blocks it. In the context of Ukraine's European integration, this linkage acquires particular weight, as

harmonisation with the acquis communautaire establishes new minimum requirements for agri-food systems.

Post-war recovery creates additional conditions for the revision of the strategic management architecture of the agri-food system. The restructuring of land relations, the need for credit support, and the development of marketing infrastructure generate an objective demand for new forms of coordination. The cooperative form of organisation under these conditions can serve as a mechanism for overcoming threshold effects of scale for small producers, providing them with access to shared resources, marketing infrastructure, and information platforms that are unattainable for individual farms. At the same time, the specific context of Ukraine's European integration combined with post-war realities creates a normative-institutional dimension that is not fully covered by any of the existing theoretical approaches. This gap underlines the need for new methodological developments oriented specifically towards the managerial application of the proposed architecture.

The proposed understanding of the agri-food system occupied a specific position relative to existing approaches and had clear implications for managerial practice. Unlike GVC analysis by G. Gereffi *et al.* (2005), who described predominantly the vertical transmission of requirements and retains a linear logic, the proposed approach accentuated the non-linearity of feedback loops as a constitutive feature of the system. Unlike the HLPE (2017) report, which offers an analytical framework but not a managerial apparatus, the proposed four-level architecture was oriented towards identifying "tension points" between levels – places where contradictions in managerial logics generate systemic dysfunctions. The grain value chain can serve as an illustrative case. The operability of the proposed architecture was demonstrated using the Ukrainian grain value chain, which is simultaneously one of the most well-documented cases of inter-level disruption. At the micro level, grain production is characterised by sharp polarisation. Agricultural holdings with land banks of tens of thousands of hectares and integrated analytics coexist with farms of 50-200 ha that are deprived of access to both market information and quality elevator services.

The scale of consequences can be assessed quantitatively. In 2021, Ukraine harvested a record grain crop of 86 million tonnes (Reidy, 2023), whilst wheat exports totalled 20 million tonnes, representing a 10% share of the world market (FAO, 2023). The pre-war forecast for the 2021/22 marketing year projected grain exports at 63.7 million tonnes (Reidy, 2022). After 24 February 2022, the situation changed radically. Monthly export volumes fell from 5-6 million tonnes to approximately 1 million tonnes (Reidy, 2023). Wheat exports declined by 44%, from 20 to 11.2 million tonnes; the share of Black Sea ports in grain exports decreased from 96% to 69%; and transport costs more than doubled (USDA, 2023). According to CSIS estimates, Ukraine's agricultural sector has suffered over USD 80 billion in damages and losses since the beginning of the full-scale invasion, with areas under wheat reduced by 32%, maize by 27%, and barley by 37% compared to the 2021/22 marketing year (Curtis *et al.*, 2024). These figures demonstrated how a decision at the supranational level (military aggression) can cascadingly destroy coordination mechanisms at all lower levels of the architecture. At the meso level, the grain chain exhibits a typical captive coordination. Elevators and traders set quality standards, determine procurement prices, and dictate payment terms. The small producer remains a price-taker without real bargaining power. Information asymmetry here is a structural feature of the chain.

The "tension point" between the meso and macro levels manifested with full force after 24 February 2022. The government introduced restrictions on grain exports to secure the domestic market (FAO, 2023). This decision, rational at the macro level, severed contractual obligations at the meso level and undermined the financial sustainability of producers at the micro level. The Black Sea Grain Initiative (July 2022 – July 2023) became an example of fourth-level coordination that temporarily compensated for the dysfunction of the third. During the year of the Initiative's operation, nearly 33 million tonnes of grain and other food products were exported (Curtis *et al.*, 2024). The tension between the third and fourth levels assumed a new form in 2023-2024. In April 2023, five EU countries (Poland, Hungary, Slovakia, Romania, and Bulgaria) imposed bans on the domestic import of Ukrainian grain under pressure from local farmers. It was through these countries that alternative routes for Ukrainian grain exports ran. The European Commission secured only a temporary compromise: a ban on the sale of four categories of grain (wheat, maize, rapeseed, and sunflower) in five border countries whilst maintaining transit. After the EU ban expired in September 2023, Poland, Hungary, and Slovakia introduced unilateral national restrictions contrary to the European Commission's decision. Ukraine filed complaints with the WTO (Albaladejo Román, 2023). This episode is illustrative, since formal harmonisation of trade regimes, declared at the fourth level, can be effectively blocked at the third level through domestic political pressure, and decisions taken to protect one national market cascadingly affect the financial sustainability of producers in another country.

This example did not constitute a full-scale empirical study – disaggregated data by producer categories and primary surveys would be necessary for that. However, it demonstrated that the proposed architecture was capable of identifying specific inter-level contradictions and serving as a basis for designing managerial interventions. Without the four-level perspective, a decision on export restrictions is analysed only at the macro level, whilst its cascading consequences for the meso and micro levels remain outside of attention. It is precisely the capacity to trace these cascades that distinguishes the systems approach from traditional sectoral analysis. Comparison with the theoretical traditions of strategic management confirmed that the resource-based view of J. Barney (1991), the dynamic capabilities concept of D.J. Teece *et al.* (1997), and the competitive forces model of M.E. Porter (1998) do not scale to the systemic level without substantial adaptation. All three approaches were developed for the micro level and treat the environment as an external given. At the level of the agri-food system, the environment becomes an integral part of the management object. The strategic horizon encompasses the transformation of the "rules of the game"

themselves: quality standards, regulatory regimes, and institutional configurations.

The MLP of F.W. Geels (2002) has demonstrated analytical value for describing socio-technical transitions. The systematic review by F. Elsner *et al.* (2023) confirmed the wide application of the MLP to ongoing sustainability transitions in agri-food systems, while documenting the predominantly qualitative and descriptive character of these analyses. The explanatory power of the MLP lies in the fundamental asymmetry of stability between the three levels of the model. The regime, as the dominant socio-technical configuration, tends towards self-reproduction through accumulated investments and institutional inertia. The niche is a space with relaxed selection requirements where new configurations develop without direct competition with the mature configuration. The landscape acts as external pressure from slow macrostructural shifts. A transition occurs when landscape pressure coincides with sufficient maturity of niche innovations.

The MLP, despite its analytical potential, has long been characterised in the literature as an explanatory rather than a normative framework. It is strong at retrospectively reconstructing how transitions have unfolded, but offers limited prescriptive guidance on how a desired trajectory might be achieved. An additional complexity is that the agricultural "regime" is considerably more heterogeneous than the energy one. In Ukraine, the 'regime' is plural and internally contradictory, whilst the niche of innovative technologies operates under varying institutional environments depending on the region and type of production. This heterogeneity constitutes the entry point for methodological refinement.

▸ Conclusions

The agri-food system is a qualitatively different type of object compared to an enterprise, an industry, or a supply chain. It is a multi-level socio-technical configuration in which the system-forming attribute is the organisation of feedback loops around the production, distribution, and consumption of food. The distinction from an "industry", a "market", or a "supply chain" is methodological: these categories do not account for feedback loops between levels of aggregation, and consequently fail to capture systemic non-linearity. Three structural subsystems of the agri-food system (functional, institutional, and managerial) have been identified. Their interaction is mediated by information flows. It has been demonstrated that equating the agri-food system with the functional subsystem is a widespread methodological error that narrows the subject of strategic management to the technical modernisation of individual links. The quality of the institutional subsystem fundamentally determines whether it enables transformation or blocks it.

A four-level architecture of the agri-food system (micro, meso, macro, and supranational levels) has been developed as an analytical tool for identifying "tension points" between levels. Each level possesses its own managerial logic and coordination mechanism. The transition between levels signifies a change in the type of coordination. The non-linearity of feedback loops between levels and the impossibility of predicting the systemic outcome from the sum of local decisions transform the agri-food system into an object of strategic management. The grain value chain case with quantitative indicators (44% decline in wheat exports, monthly volumes falling from 6 to 1 million tonnes, import bans by five EU countries) confirmed the architecture's capacity to identify cascading inter-level contradictions. Information flows are the connective link between the subsystems and between levels of aggregation. For the five information flow quality criteria (completeness, timeliness, bidirectionality, accessibility, and institutional embeddedness), indicators and an ordinal assessment scale have been proposed. Ensuring end-to-end information flows in contemporary agri-food systems requires appropriate technological and institutional infrastructure.

Prospects for further research are linked to the development of a methodological apparatus for assessing the maturity of agri-food systems at the sub-national level, including the empirical testing of the proposed information flow assessment scale on specific chains, the specification of management mechanisms for transformation under the conditions of European integration and post-war recovery of Ukraine, and the verification of the proposed four-level architecture using primary data.

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Агропродовольча система як об'єкт стратегічного управління: концептуалізація та багаторівнева архітектура

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► **Анотація.** Розбіжність між обсягами світового виробництва продовольства та масштабами хронічної продовольчої небезпеки свідчить про те, що критичні чинники стійкості аграрного сектору формуються поза межами окремого підприємства чи ринку. Традиційні аналітичні категорії (галузь, ланцюг постачання, аграрний ринок) не враховують зворотні зв'язки між рівнями агрегації і, отже, не забезпечують адекватної основи для стратегічного управління. Метою цієї статті було обґрунтувати сутність агропродовольчої системи як цілісного багаторівневого об'єкта стратегічного управління, визначити її структурні підсистеми та продемонструвати роль інформаційних потоків як системоутворюючої ознаки. Методологічною основою дослідження стали системний підхід, порівняльний аналіз теоретичних фреймворків (аналіз глобальних ланцюгів вартості, системний підхід HLPE/FAO, багаторівнева перспектива) та метод теоретичного синтезу. Вибір фреймворків здійснювався за критеріями масштабу аналізу (лінійний – системний), операційної придатності для управління та охоплення зворотних зв'язків. Було запропоновано визначення агропродовольчої системи як багаторівневої соціотехнічної конфігурації, системоутворюючою ознакою якої є організація зворотних зв'язків навколо виробництва, розподілу та споживання продовольства. Виокремлено три структурні підсистеми (функціональну, інституційну та управлінську), взаємодія яких опосередкована інформаційними потоками. Розроблено чотирирівневу архітектуру агропродовольчої системи як аналітичний інструмент стратегічного управління. Для кожного з п'яти критеріїв якості інформаційних потоків запропоновано індикатори та шкалу оцінювання. На прикладі зернового ланцюга вартості України продемонстровано здатність архітектури ідентифікувати каскадні міжрівневі суперечності, зокрема між регуляторними рішеннями макрорівня та контрактними зобов'язаннями мезорівня. Результати можуть бути використані при розробці національних стратегій розвитку агропродовольчих систем в умовах євроінтеграції. Запропонована шкала оцінювання інформаційних потоків слугує діагностичним інструментом для органів аграрної політики та галузевих асоціацій

► **Ключові слова:** інформаційні потоки; ланцюги вартості; інституційне середовище; цифрова трансформація; продовольча безпека; координаційні механізми