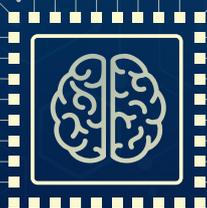


INNOVATIVE PRINCIPLES of UKRAINE'S EUROPEAN INTEGRATION

natural resource management
economics, projects and digitization



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INTEGRATION
NATURAL RESOURCE MANAGEMENT ECONOMICS, PROJECTS AND
DIGITIZATION**

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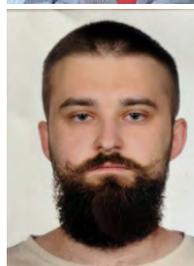
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Ukraine's path to European integration is not only a process of political alignment, but above all a profound transformation of economic identity. The green economy represents our commitment to future generations and the protection of natural capital, while digitalization provides us with tools for precise, transparent and modern governance of the country. Together, these two pillars form a solid foundation for innovative agriculture, environmental security and a prosperous society within the common European home.

Authors

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INTRODUCTION

The problem of low efficiency in the management of soil and water resources in conditions of intense competition on agricultural markets requires institutional, legislative and regulatory support, as well as socio-ecological and economic justification for the rational use of the country's natural capital in the context of the implementation of the Association Agreement between Ukraine and the EU. Strengthening ecological and economic security in the use of soil and water resources will bring systemic and synergistic effects that will ensure the balanced functioning of sectors in line with strategic national and regional interests. This monograph examines: solutions for improving the use of water and soil resources; directions for increasing the production of competitive, high-quality agricultural products; socio-ecological and economic foundations of agricultural environmental management; conceptual frameworks and applied methodologies for the development of ecological production; tools to attract investment and support diversification in agro-industrial production and exports of finished products. Together, these areas contribute significantly to the implementation of the Association Agreement between the EU and Ukraine.

In Ukraine, the priority task is to justify the diversification of agricultural production under conditions that ensure the preservation of soil and water resources, particularly with regard to the emerging land market and the obligations arising from the Association Agreement between Ukraine and the EU.

The research also reveals the socio-ecological-economic foundations for ensuring the security of land and water resource use in unified territorial communities within the framework of smart specialisation approaches and the harmonisation of legislative and regulatory frameworks in line with the country's European integration trajectory. It also sets out principles for ensuring national security in the context of the globalisation of world food and energy markets. The results of the project have a clear geographical dimension, are based on interdisciplinary research, use unique scientific approaches and respond to the needs of national development within the framework of European integration.

CHAPTER 1. METHODOLOGY OF TOOLS FOR SOLVING ENVIRONMENTAL PROBLEMS IN THE AGRICULTURAL SECTOR OF UKRAINE

1.1. Methodological and institutional foundations for the implementation of Ukraine's European integration

European and Euro-Atlantic integration is a strategic direction chosen by the Ukrainian people and enshrined in the Ukrainian Constitution. It requires systematic and effective work by all state institutions, clear coordination, harmonious functioning of all branches of government and strong political support.

The signing of the Association Agreement with the EU was a milestone in Ukraine's development. The benefits for Ukraine include the implementation of EU directives and regulatory documents. The aim is to gradually harmonise Ukrainian legislation with EU standards while preventing trade barriers. The agreement allows Ukrainian producers not only to enter the EU market, but also to increase food safety for domestic consumers. To this end, it is necessary to adapt European food safety standards, create conditions for the introduction of quality control systems and eliminate the risks of corruption in the form of excessive control and lengthy permits. Issues related to improving national legislation in the field of food safety and quality were the subject of interest of experts in the field of law and economics: O. Borodina, V. Yermolenko, T. Kovalenko, V. Korniyenko, V. Kuril, T. Kurman, V. Mamutov, K. Nastechko, R. Petrov, O. Polivodsky, P. Skrypchuk, V. Semchik, A. Stativka, N. Titova, V. Urkevich, V. Fedorovych, T. Churilov, Yu. Shemshuchenko, I. Shumilo, V. Yurchishin and other scientists [1-5].

The topic of harmonising Ukraine's legislative and regulatory documents with those of the EU in all sectors of the economy, particularly in the field of protection and rational use of natural resources, is partially covered in the works of authors such as A. Boyar, T. Buryachok, I. Zapatrina, T. Goncharov, F. Gryshchenko, A. Grebonyuk, O. Ivanov, S. Osika, R. Ovcharenko, K. Koshman, L. Kavunencko, Yu. Kozhedub, Z. Mishchuk, O. Pugachevska, H. Filipchuk, Ya. Yuzkiv, O. Chuvpilo and others. Among foreign authors, the works of M. Lemmel, F. Manié, D. Hanson, A. Bailey, M. McKinney, N. Bevers, S. Reynolds, N. Muis and others stand out.

Ukrainian scientists, including O. Veklich, V. Shevchuk, Yu. Stadnytsky, L. Hryniv, T. Halushkina, V. Kovalev, B. Danilysyn, A. Sokhnych, M. Khvesyk and others. New approaches to preserving natural capital in the context of shaping ecologically balanced economic development and European integration have been developed by scientists such as G. Daly, J. Cobb, R. Costanza, S. El Serafi, J. Tinbergen, R. Huyting and others. However, this issue has not received sufficient attention in the agricultural sector and in the field of land use.

The work of foreign scientists has influenced the formation and development of the scientific field of security research in various spheres: O. Belova, V. Bohdanovych, V. Horbulin, D. Dubov, B. Kachynskiy, O. Korniiievskiy, V. Kosevtsov, V. Mandrageli, N. Nyzhnyk, O. Lytvynenko, A. Semenchenko, H. Sytnyk, M. Barnett, A. Bellamy, K. Buza, B. Buzan, T. Weiss, O. Wever, P. Williams, J. Duffield, H. Dexter, D. Joseph, R. Jones, B. Evans, A. McGrew, J. Reid, E. Thompson, R. Ulman, D. Held, J. Hertz, L. Friedman, M. Foucault, D. Chandler and others. Among the researchers of this phenomenon, personalities such as J. M. Anders, F. Burbot, J. Joseph, B. Evans, K. Zebrowski, M. Cavellti, M. Kaufmann, K. Christensen, M. Cooper, P. Martin-Brine, G. Lasconjarias, V. Proaga, J. Reid, J. Rensel, J. Walker, K. Fieder, D. Chandler and others.

The development of conceptual approaches to ensuring national security, the development of systems theory and the creation of a separate field of research in natural resource management have led to the extension of the concept of security to the use of agricultural natural resources, including land use [1-5].

One of the main methods of researching security issues is the systems approach. At the national level, security means the protection of the national interests of society. It should be noted that there is no single established definition of the term «security» or an exclusive list of areas of its application in the world. Currently, there are different approaches to interpreting this concept due to its systemic and interdisciplinary nature (Fig. 1.1).

The adaptation of legislation is carried out with the aim of ensuring the compliance of Ukrainian legislation with the obligations arising from international agreements on cooperation between Ukraine and the EU in the field of with a view to developing national legislation in line with EU legislation and creating a legal framework for Ukraine's integration into the EU.

The adaptation of Ukrainian legislation is carried out in the following order:

- identification of *acquis communautaire* acts governing legal relations in the relevant area;
- conducting a comprehensive comparative analysis of the regulation of legal relations in the relevant area in Ukraine and the EU;
- preparation of recommendations for harmonising ukrainian legislation with the *acquis communautaire*;
- conducting an economic, social and political analysis of the consequences of implementing the recommendations;
- creating a list of legislative tasks;

- preparing draft laws of Ukraine and other regulatory acts included in the list of legislative tasks and getting them passed;
- monitoring the implementation of Ukrainian legislation.

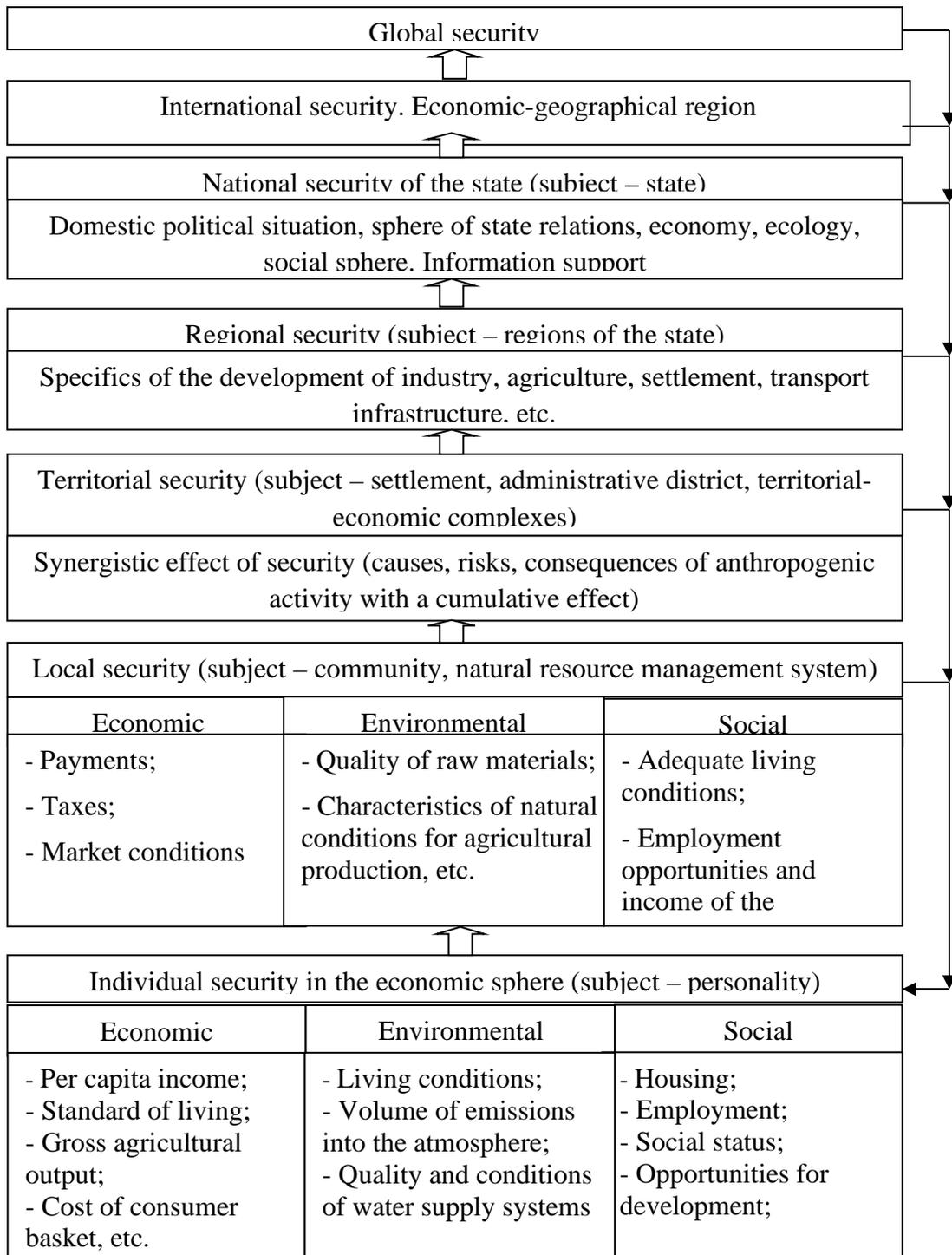


Fig. 1.1. Security levels (security assurance model in a systemic society – water supply systems)

The adaptation of Ukrainian legislation is a systematic process involving several consecutive stages, each of which aims to achieve a certain degree of harmonisation of Ukrainian

legislation with the *acquis communautaire*. The following methodological principles and provisions form the basis for the implementation of European integration processes:

- the principle of strategic orientation and compliance with state policy in various spheres of state functioning;
- the principle of state support;
- principles of expediency (with regard to current national interests, economic conditions and opportunities in Ukraine);
- the principle of foresight, efficiency and minimum costs, as well as consistency with EU development trends;
- principles of systematicity and priority setting: this means a comprehensive approach to the process of harmonising Ukrainian legislation with EU legislation, with priority given to setting goals and tasks;
- the principle of scientific justification, which means supporting the development of basic and applied research and supporting the organisation of comprehensive scientific support for the adaptation of EU regulatory acts;
- the principle of consistency and coordination in the work of government bodies in implementing measures to adapt legislation;
- the principle of consolidation of government bodies and civil society institutions with a view to developing mechanisms for planning, implementing and monitoring adaptation processes.

The process of improving and adapting legislation can therefore be evaluated by establishing an appropriate monitoring system, which is a fundamental element of national programmes (plans) for harmonising all types of legislation.

The vector of Ukraine's European integration also takes into account global processes taking place in organisations such as the UN, FAO, ISO and other global organisations. The international community faces a number of social, economic and environmental challenges. For example, the United Nations Sustainable Development Goals serve as a platform for collective action on these issues at the international level, thereby strengthening future resilience through the promotion of economic growth. The standards and regulatory documents developed by ISO are largely harmonised with EU directives and standards. Within a single system, they create conditions for international trade and technological development. Developing countries can gain significant benefits by adopting ISO standards. At the state level, standards can be used to support public policy and ensure good regulatory practice. At the private sector level, businesses can use standards to ensure that their products and services are fit for their intended purpose. When products and services are developed according to common standards, consumers also benefit

because they can be confident that such products and services are of high quality, safe and environmentally friendly.

At the level of global and European harmonisation, ISO standards (in virtually all areas of natural resource management) are used and adopted at national level in various countries. ISO standards are becoming more important at international level and will be used effectively if they adequately reflect the interests of the countries involved.

A less explored issue is the implementation and harmonisation of regulatory documents relating to ‘natural capital’ as an economic category, which was introduced into scientific circulation in the 1980s. The need to use the category of «natural capital» arose from the need to distinguish between aggregates that characterise reserves and flows in the economy. According to estimates by the National Academy of Sciences, the real value of Ukraine’s natural capital is \$320-380 trillion, of which 83-88% is represented by natural resource wealth. This means that the country’s natural capital per capita is approximately \$2 million. This is an exceptionally high amount. As Ukraine seeks to integrate into the European economic area, political, legal, organisational and environmental measures for the protection, use and restoration of natural capital must be geared towards the requirements of EU Member States (Fig. 1.2).

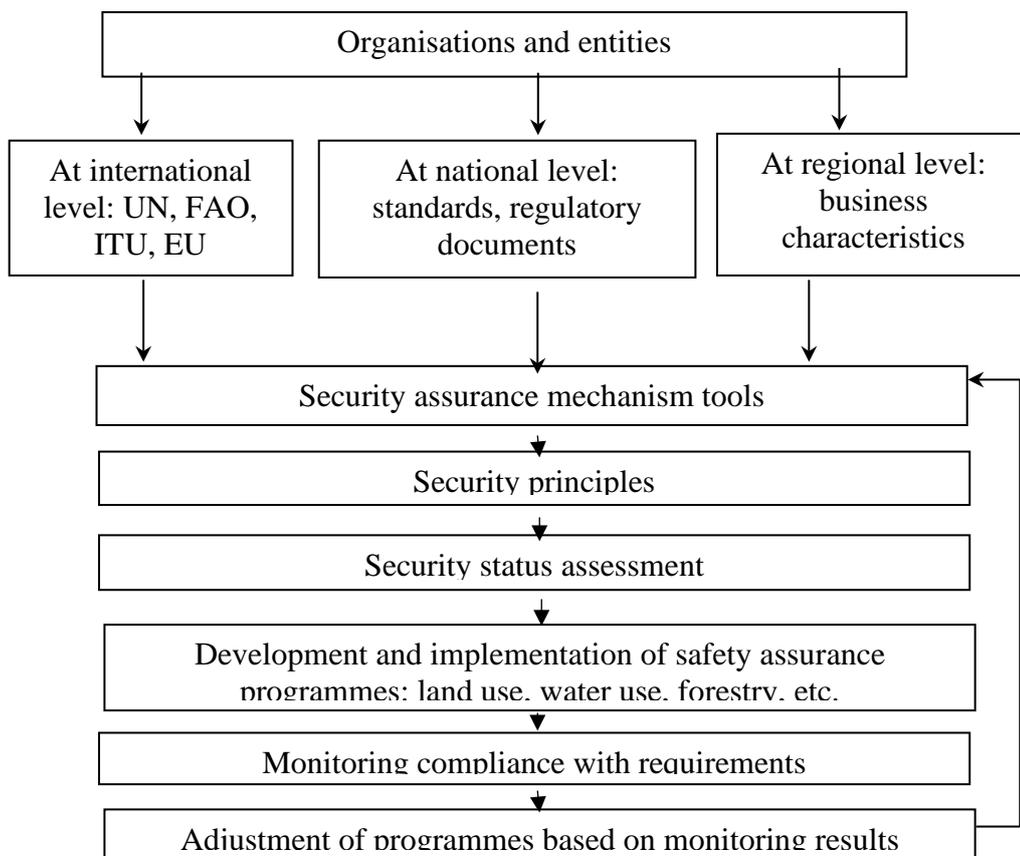


Fig. 1.2. Taking into account the requirements of European integration in ensuring the security of natural resource management

Another vector related to European integration is Ukraine's accession to the WTO in accordance with the provisions of the Association Agreement with the EU on the application of sanitary and phytosanitary measures, as this is an area where state authority, commercial interests, environmental issues, public health and safety issues, and acceptable limits of technological development.

Currently, the WTO is the largest mechanism for integrating national legislation and international agreements. WTO membership requires that all national legislation be harmonised with the provisions of the agreements. WTO rules now permeate all areas of a country's economic activity. This brings to the fore the question of the relationship between national and international legislation (in this case, WTO normative acts). WTO law in the national legal system of an acceding state is considered part of national law. One manifestation of the interaction between WTO law and the domestic law of member states is the phenomenon of the so-called «direct effect» of WTO norms. The direct effect of WTO law makes it possible to challenge domestic norms by referring to WTO agreements. Given the principle of state sovereignty, each state decides independently whether to follow the doctrine of direct effect when implementing international trade law, in particular WTO law. Currently, most WTO member countries (including major economically developed countries such as the EU, the US, Japan, India, Canada and others, whose share of world trade exceeds 70%) have rejected the direct effect of WTO law. WTO agreements also do not explicitly require the recognition or rejection of the «direct effect» of WTO agreements. From a methodological point of view, the arguments of countries that do not recognise the direct effect of WTO rules are interesting. For example, the EU – one of the key players in the WTO – clearly accepts only those WTO decisions and standards that do not hinder its ability to implement sufficient protectionist policies.

An analysis of the prospects for the development of Ukrainian legislation in the field of natural resource management suggests three most likely conceptual paths (Fig. 1.3).

The first path is WTO-oriented, which means that it focuses on maximum international harmonisation of requirements in all areas. This path has both positive aspects (simplification of trade, creation of legislation in line with international standards) and negative aspects (dominance of the interests of developed countries).

The second path is EU-oriented, which means that it focuses on approximating legislation to EU legislation. The positive aspects of this path include continuous legal progress and the greening of agricultural activities. The negative aspects of European integration in the field of legislative development include: hasty copying of legal approaches and principles without taking into account evolutionary differences; lack of adequate transition periods; ignoring national specificities and problems; and surrendering a significant part of legal sovereignty in this area.

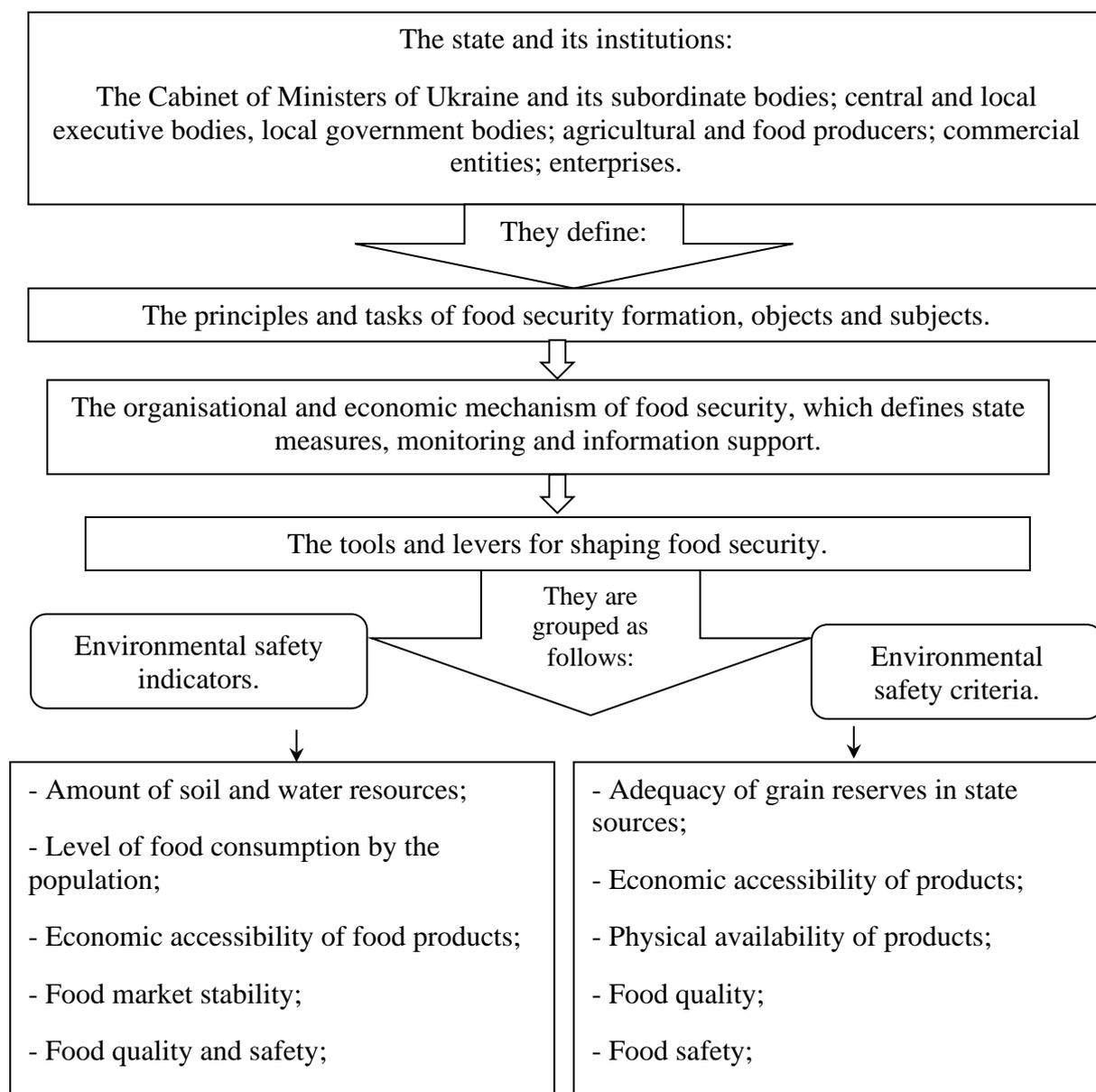


Fig. 1.3. Creation of an organisational and economic mechanism for national food security

The third way is oriented towards national interests, which means that it focuses on the national interests of Ukraine and the interests of its population as the main principles in the development of national legislation. According to these methodological positions, any legislative reform (alignment, adaptation, harmonisation, etc.) should only be carried out in areas at a pace and to an extent that correspond to Ukraine's national interests, accompanied by the necessary transition periods and appropriate protective mechanisms aimed at sustainable development. The legal instruments of a nationally oriented approach do not involve copying foreign legal acts, but rather adopting the principles and methodological approaches that have led to the achievement of the desired level of development.

A nationally oriented path of environmental legislation development does not mean legal isolation. On the contrary, globalisation transformations mean that the regulation of harmonisation processes cannot be limited to the national level alone. There is currently a demand for the development of uniform regulation of these issues while maintaining the ability to adapt basic rules based on local specifics. The need for harmonisation is determined by several key factors: ecological (protection of the life and health of plants, animals and humans from risks of transnational significance); economic (significant simplification of international trade); social (harmonisation of food safety indicators and public health standards). It is important to maintain the right balance between the objectives and the methods used to achieve them, namely: harmonisation processes should not be seen as an end in themselves, but as a means of satisfying Ukraine's national interests in the field of environmental management.

One of the tools of European integration is EU directives and standards (a tool of European integration [7]), which are harmonised with the indicators of the International Trade Centre (ITC), a multilateral agency with a mandate from the World Trade Organisation (WTO) and the United Nations. The ITC database contains 1,650 basic indicators that allow standards to be compared on the basis of: environmental performance (protection of forests, soil, water, biodiversity, climate, etc.); social performance (e.g. protection of human rights, labour rights, local communities); governance and ethical indicators (supply chain responsibilities); quality indicators (products, food systems); operational indicators (guarantee, standard setting, monitoring, complaints). Requirements for standards and standardisation systems are assessed on the basis of these indicators.

A key and unique feature of the Standards Map tool (ITC database) is that all information available online is verified and quality-checked by each organisation involved in standardisation. In general, significant updates to standards are made every two years. The control indicators and information displayed on the Standards Map are therefore up to date, accurate and frequently revised to reflect the latest changes in standards and international agreements relating to the functioning of states.

The effectiveness of ITC's work is assessed on the basis of the contribution of ITC projects to the 2030 Global Agenda, project results and the effectiveness of its activities. Planning and monitoring of results at each level is based on both quantitative and qualitative targets. The 2030 Agenda recognises that international trade and investment are tools for achieving sustainable development. The UN General Assembly adopted the 2030 Agenda for Sustainable Development. At the same time, the ITC identified 10 goals and related tasks to which its work directly contributes. In 2020, ITC added Goal 13 on climate action as Goal 11, given the increased attention the organisation is paying to environmental goals. From 2022 onwards, according to its strategic

plan for 2022-2025, ITC will contribute to the achievement of all 17 goals and related targets. Agenda 2030 states that the Sustainable Development Goals are interlinked and indivisible.

The core of ITC's work is to strengthen the competitiveness of small businesses and increase their opportunities for profit. ITC's strategic plan for 2022–2025 balances environmental and economic goals. The Green To Compete initiative offers an opportunity to leverage green technologies. The ITC website and database, the ITC Standards Map and the ITC Sustainability Map increase the transparency of sustainable development standards, making them more accessible to businesses.

The main directions for ensuring food security in Ukraine should therefore be: harmonisation of national standards for agricultural products with EU, FAO, ITC and the most developed countries' standards. State regulation of food security is a system that includes economic, financial, legal, organisational and social measures aimed at ensuring the stability and efficiency of the development of agricultural production and processed products, as well as meeting the needs of the population for food of adequate quality in sufficient quantities and at prices affordable to the country's population.

The main methods of state regulation of food security are market analysis and forecasting of the situation on the food market; designing and organising the implementation of state and regional target programmes to improve the food complex; ensuring control.

The main tasks of state regulation regarding the necessary level of food security in Ukraine are:

- growth in agricultural production through better use of natural resources, technological and regulatory potential for food security in the national economy;
- stabilisation of market conditions and price fluctuations for agricultural products and foodstuffs;
- achieving food consumption levels based on scientifically sound standards;
- ensuring food availability in line with the purchasing power of the population and ensuring the necessary food quality;
- ensuring food security by increasing exports of food products (while satisfying the needs of the domestic market) and reducing (replacing) food imports.

Most policy measures to ensure food security should be implemented at the state level in order to coordinate the activities of all participants. The implementation of such a complex process requires a combination of state agricultural, economic and social policies. The activities of the state and society in shaping food security should be based on an objective, comprehensive analysis and forecasting of the situation in the field of food supply, consumption and the interaction of key elements of the country's food security system, as confirmed by [8].

The effectiveness of the organisational and economic mechanism of food security in market conditions is primarily determined by such parameters as: standardisation and optimisation of food production, sales and consumption; system objectives corresponding to changing needs that evolve and change with the progress of society and the world. Currently, state funding for the agricultural sector is negligible. Moreover, not all planned state expenditures have an impact on the formation of effective directions for the development of the agricultural sector, since a significant part of the budgeted expenditures only maintains its current position. There is no food shortage in Ukraine, but consumption levels are falling due to reduced purchasing power, low wages and high prices. The country's food security can only be ensured by an efficiently functioning agricultural sector that uses resource-saving technologies, innovations in production processes, has a strong material and technical base and produces competitive products. It is therefore necessary to clearly define the priority directions for agricultural development and secure sources of investment. A well-established mechanism for the functioning of production and economic relations in the agricultural sector will contribute to increased self-sufficiency in various products and ultimately ensure stable food security for the country, the development of rural infrastructure and the preservation of labour potential.

The future of the agricultural sector lies in diversifying the development of agricultural production through increased capitalisation and investment attractiveness of agricultural enterprises, the introduction of market circulation of agricultural land, support for family farms, the implementation of modern adaptive environmentally safe agricultural technologies based on the latest scientific and technological advances, taking into account the regional and environmental-climatic characteristics of the territory, and the creation of mechanisms « « to create added value in local communities, which will contribute to the inclusive development of rural and settler communities.

Recent history shows that in order to protect people from hunger and malnutrition in times of war, global food and nutrition security will be strengthened through the Global Alliance for Food Security, for which an additional \$4.5 billion will be allocated. As a result, the total commitments of the G7 countries to finance food security measures worldwide will reach USD 14 billion [9].

However, Russia's military aggression has suspended the active realisation of Ukraine's significant agricultural potential, exacerbating the global food crisis and putting countries at risk of losing acceptable levels of food and access to it. Under these conditions, the WTO faces the difficult task of maintaining the openness of food and agricultural markets in order to prevent uncontrollable volatility and an increase in global food shortages [10]. The global community therefore needs to build an international security architecture, an essential element of which must

be a mechanism to prevent an aggressive country from using food as a weapon, which would cause significant damage to global food security. It is assumed that the WTO, together with the UN and other interested international organisations, can take on the task of implementing this initiative. The WTO's passive response to the war against Ukraine and the actual absence of mechanisms to influence a WTO member involved in an aggressive war has led global players and other democratic countries around the world to provide assistance to Ukraine primarily in a bilateral format. The indicator of countries' interest in the continued functioning of the WTO is, in fact, their activity in developing proposals for the modernisation of the organisation. In this regard, the most detailed proposals for WTO reform have been put forward by the EU. The European Union was the first to propose a concept for modernising the WTO. The main areas of modernisation are formulated as follows: aligning WTO rules with the needs of the modern global economy; strengthening the WTO's role in trade monitoring; improving the WTO dispute settlement system.

1.2. Institutional support for European integration

European and Euro-Atlantic integration is Ukraine's strategic direction, chosen by the Ukrainian people and enshrined in the constitution, which requires thorough, systematic and effective work by all state institutions, clear coordination, the smooth functioning of all branches of government and strong political support [11].

The signing of the Association Agreement with the EU marked a milestone in Ukraine's development. Among the benefits for Ukraine is the implementation of EU directives and regulations. The economic part of the Association Agreement between Ukraine and the EU contains provisions to ensure the safety and quality of food products. The aim is to gradually harmonise Ukrainian legislation with EU standards while removing barriers to trade. Improving domestic legislation in line with the European model is therefore not only desirable but also the only possible way to meet commitments. The agreement not only gives Ukrainian producers access to the EU market, but also increases food safety for domestic consumers. To this end, it is necessary to adapt European food safety standards, create conditions for the introduction of quality control systems and eliminate the risks of corruption in the form of excessive controls and lengthy licensing procedures.

For Ukraine, food safety, which is a priority area of EU policy, is the main direction for the development and improvement of the legislative framework. A distinction is made between food safety and quality legislation and food raw materials. Safety issues are regulated at the legislative level, compliance with the established requirements is mandatory, and violations result in liability. Safety requirements are mainly contained in regulations, which are laws with direct effect.

The creation of a harmonised food safety system is the result of a long-term process of deepening EU integration. There are four phases in the development of EU food law. The first phase is characterised by the application of vertical directives relating to specific groups of goods. In the second phase, horizontal legislation was implemented, laying down uniform requirements for general aspects of all food products. The third phase is based on risk analysis and is in line with the principles of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures and is related to the standards, guidelines and recommendations of the Commission's Codex Alimentarius. To ensure this approach, general food law was adopted – EU Regulation No 178/2002, which laid down the basic principles of the food control system, established the European Food Safety Authority and regulated emergency response procedures, thereby initiating the centralisation of food safety. The fourth phase is the creation of a single European food safety system that will fall entirely within the competence of the EU [12].

Cooperation in this area is regulated in Chapter 17, 'Agriculture and Rural Development', Section V, 'Economic and Sectoral Cooperation', of the Association Agreement and in Annex XXXVIII. Progress in fulfilling commitments under the Agreement Pulse system: support for rural development through the gradual harmonisation of Ukrainian legislation with EU legislation in areas such as agricultural product quality policy, food products and alcoholic beverages, organic farming, genetically modified cereals, biodiversity, standards for trade in plants, seeds, products of plant origin, fruit and vegetables, standards for trade in live animals and animal products; improving the competitiveness of agribusiness, the efficiency and transparency of agricultural product markets and investment conditions; promoting innovation through research and promoting advisory systems for agricultural producers.

The implementation of EU law into Ukrainian legislation has resulted in a steady increase in trade between Ukraine and the EU in agricultural and food products. The main content and obligations of Ukraine regarding European integration processes are set out in Chapter 17 'Agriculture and Rural Development' of Section V 'Economic and Sectoral Cooperation'. In this area, the Association Agreement focuses on supporting the development of agriculture and rural areas, in particular through the gradual harmonisation of policies and legislation in areas such as: agricultural product quality policy, food products, organic farming, genetically modified cereals, biodiversity, standards for trade in plants, seeds, products, fruit and vegetables, and standards for trade in live animals (Fig. 1.4).

Cooperation between Ukraine and the EU in the field of agriculture and natural resource management covers the following areas:

- promoting mutual understanding in the field of agricultural policy and development policy for agricultural regions;

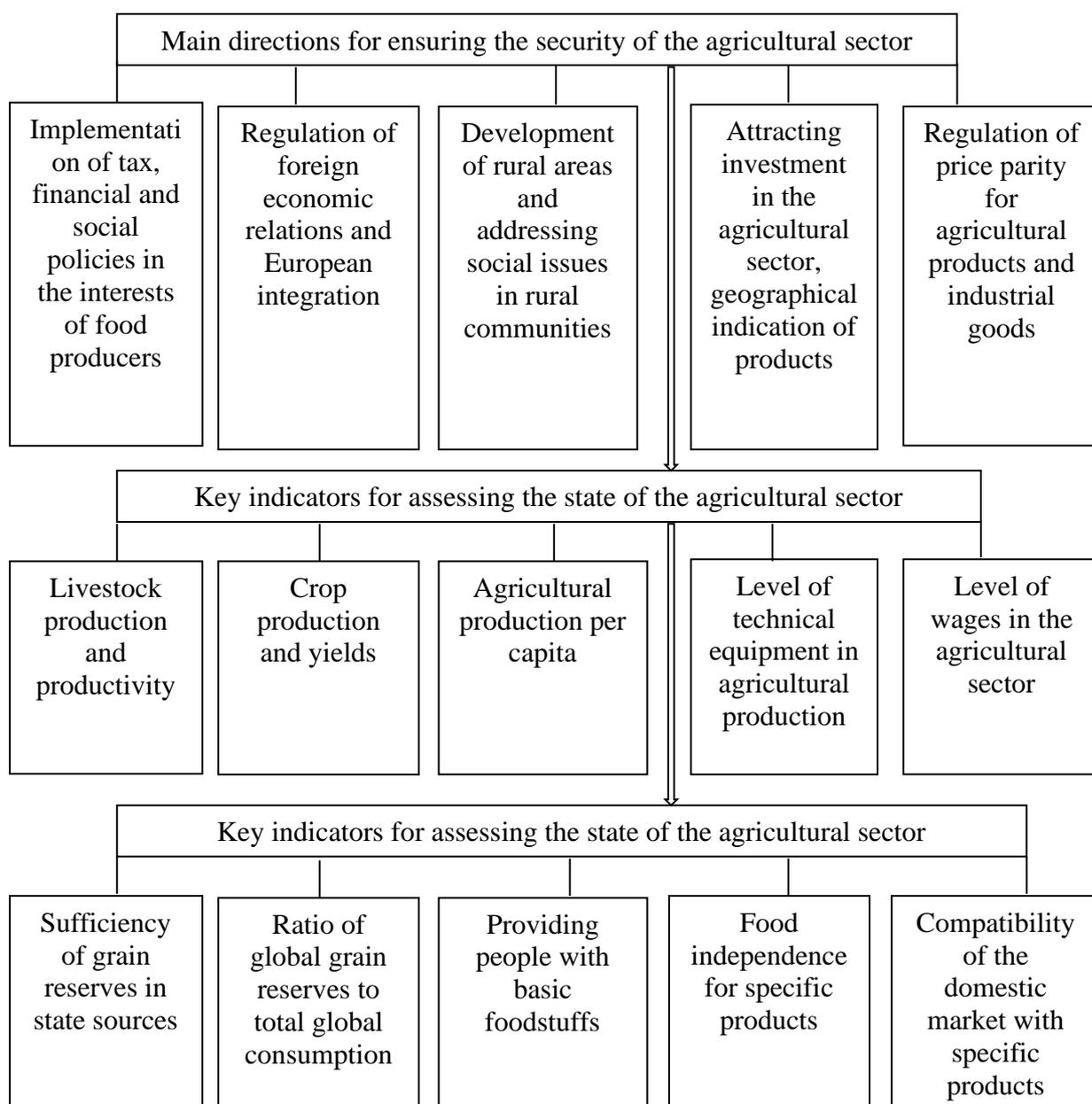


Fig. 1.4. Key areas for ensuring the security of the agricultural sector

- strengthening administrative capacities at central and local level in areas such as planning, evaluation and implementation of these policies;
- promoting the development of modern and sustainable agricultural production, including support for the use of environmentally friendly production methods and biotechnologies, in particular through the introduction of best practices in these areas;
 - exchanging knowledge and best practices in the management of natural resources in agriculture with a view to preserving the country’s natural capital;
 - strengthening the competitiveness of the agricultural sector, improving the efficiency and transparency of markets and creating favourable conditions for investment;
 - disseminating knowledge through training and information events;

- promoting innovation through scientific research and support for the expansion of services for agricultural producers;
- promoting the harmonisation of issues addressed within international organisations;
- exchanging best practices on mechanisms to support agricultural policy and agricultural regions;
- implementation of agricultural product quality policies in the areas of standardisation, production requirements and quality systems.

One of the bodies responsible for this area in Ukraine is the Ministry of Agricultural Policy and Food of Ukraine. The main positive results of European integration include:

- broader opportunities for companies in the field of cooperation and exchange of knowledge, experience and technologies;
- the adaptation of standards for agricultural products and agricultural market infrastructure and easier access to the EU market for products from Ukrainian agricultural companies;
- improving the quality of agricultural products through higher environmental production standards;
- increasing employment and prosperity in local communities in the country's agricultural regions;
- modernising state agricultural policy in line with EU legislation;
- developing agricultural market standards and infrastructure.

European food safety policy, the main principles of EU food law and the general principles of food and feed law are laid down in the EU's General Food Law Regulation. It provides a horizontal framework that underpins all Union and Member State measures relating to food and feed. The general objectives of food and feed law are:

- to ensure fair trading practices in the food sector;
- to provide a high level of protection for human life and health and to protect consumer interests;
- ensure the free movement of food and feed produced and marketed in the European Union in accordance with the General Food Law Regulation;
- promote global trade in safe feed and safe, nutritious food with a high level of consumer protection from the European Union;
- to implement appropriate measures to ensure food safety;
- regulating the traceability of risks in the food chain;
- notification through the rapid alert system for food products, etc. [13].

The Rapid Alert System for Food and Feed covers 27 countries. The alert system supports traceability by providing rapid exchange of information when a risk to food or feed safety is detected through the TRACES control and expert system. More detailed traceability requirements are set out in EU food law. Details on the traceability of food of animal origin can be found in Commission Regulation (EU) No 931/2011 and on the traceability of seedlings and seeds in Commission Regulation (EU) No 208/2013. The primary responsibility for ensuring compliance with food law, including food safety, lies with food (or feed) business operators. To enforce this principle, the competent authorities of EU countries must ensure adequate and effective controls. If food or feed products are found to be unsafe, business operators are obliged to withdraw them from the market.

Main responsibilities of food business operators:

- safety (entities must not place unsafe food or feed on the market);
- responsibility (entities are responsible for the safety of the food and feed they produce, transport, store or sell);
- traceability (operators must be able to quickly identify each supplier or recipient);
- transparency (businesses must immediately inform the competent authorities if they have reason to believe that their food or feed is unsafe);
- emergency situations (businesses must immediately withdraw food or feed from the market if they have reason to believe that it is unsafe);
- prevention (operators must identify and regularly check critical points in their processes and ensure that control measures are applied at these points);
- cooperation (operators must cooperate with the competent authorities in risk mitigation measures).

In the area of food safety, product quality and management of agricultural natural resources, urgent legal regulation of food safety and quality is carried out in accordance with the laws of Ukraine «On State Support of Agriculture of Ukraine», ‘On Food Safety and Quality’, ‘On Ensuring the Hygienic and Epidemiological Well-being of the Population’, ‘On Veterinary Medicine’, ‘On Consumer Protection’, ‘On Standardisation’, ‘On Conformity Assessment’ and other regulatory acts. According to the Law of Ukraine «On State Support of Agriculture of Ukraine», food security is understood as the protection of human life interests, expressed in the state guarantee of unrestricted economic access to food products to support human life activities. The food resource balance sheet scheme must therefore comply with international standards and recommendations and be based on the concepts and methodological approaches to its compilation established by the Food and Agriculture Organisation of the United Nations (FAO).

One of the main issues contributing to the imperfection of national legislation in the field of food safety is the insufficient differentiation in the legal regulation of food safety and quality, as well as food raw materials. The Ukrainian law «On Food Safety and Quality» provides for the control not only of food safety but also of food quality. However, the EU *acquis communautaire* in this area stipulates that only safety is subject to state control, while quality is ensured exclusively by market mechanisms.

The need to transition to European regulatory principles is justified by the fact that eliminating differences in approaches to food market regulation is a key condition for creating a free trade zone for such products. To ensure food safety, it is necessary to monitor compliance with Ukrainian legislation in all sectors of the economy: food, including imported products, at all stages of production, storage, transport, processing and sale. It is necessary to eliminate the uncontrolled spread of food products obtained from genetically modified plants, using genetically modified microorganisms and microorganisms with genetically modified analogues. Harmonisation with international food safety standards should continue on the basis of fundamental research in the field of nutrition [14].

One of the tasks of the technical regulation system is to ensure that products placed on the market are safe for consumers, users and the environment, and to introduce economic policies aimed at stimulating innovation, increasing competition, reducing production costs and promoting trade by removing technical barriers. The legislation defines that the purpose of adopting technical regulations is to protect the life and health of humans, animals and plants, protect the environment and natural resources, increase energy efficiency, protect property, ensure national security and prevent commercial practices that mislead consumers (users). The conceptual difference between the European system of technical regulations lies in prioritising the safety of goods (services), their consumption and use by humans and animals, as well as providing adequate information on the properties of goods. The system is based on technical harmonisation of legislation and mutual recognition, based on the 'new approach to product regulation' and the 'global approach to conformity assessment'. Overall, harmonisation of standards is a positive factor for the development of the domestic economy, as the experience of developed countries confirms that every unit of national currency invested in standards can bring a return of 20 to 40% in profits. Countries optimise the level of use of international standards in the total number of national standards in order to protect the domestic market, support national producers and ensure the economic security of the country. The «New Approach» directives set requirements for specific categories of products, clearly and precisely defining the end result. A list of voluntary European standards is added to each of them, and compliance with these standards ensures compliance with the requirements of the directives. The application of these standards is voluntary, and

manufacturers are only required to meet safety requirements for products and production. Issues of technological innovation, quality and competitiveness of products are addressed directly by the manufacturer. Products that meet the requirements of harmonised European standards in accordance with EU directives are considered to comply with the essential requirements of the directive (presumption of conformity). Products are placed on the EU market after undergoing a conformity assessment procedure, and market surveillance is carried out by public authorities. Technical regulation in the new approach therefore focuses on product requirements in order to ensure a high level of protection for the population, with the manufacturer being directly responsible for the technical solution to these tasks. In the old certification and standardisation system, safety checks were carried out on the basis of documents (certificates), whereas in the new European technical regulation system, they are carried out by means of market surveillance methods or checks on the finished product, rather than on the manufacturing process. The EU technical regulation system thus ensures the free movement of goods and limits state interference in the economic activities of businesses.

Ukrainian consumer protection legislation also needs to be updated in line with EU consumer policy, which focuses on consumer needs rather than producer interests. The EU Consumer Policy Action Plan sets out the following priorities: consumer safety, consumer information and education, development of consumer rights, adequate compensation in the event of infringements, and enforcement. Ukraine has implemented Directive 97/7/EC of the European Parliament and of the Council on the protection of consumers in respect of distance contracts. Improvements are needed in: the harmonisation of the concepts of ‘contracts concluded away from business or office premises’ and ‘distance contracts’; the concept of ‘distance communication’; the development of initiatives to promote alternative dispute resolution mechanisms in addition to judicial protection of consumer rights; and the introduction of standardised complaint forms for the internal e-commerce market.

An important prerequisite for strengthening consumer safety in Ukraine is the introduction of a system of technical regulations harmonised with EU requirements, which will improve product quality and safety, expand market access for businesses to the EU and stimulate innovation and modernisation of production. Despite the advantages of self-certification of compliance with technical regulations, domestic businesses face threats related to the inadequacy of the institutional framework, the socio-mental characteristics of Ukrainian consumers and producers, and the presence of well-informed and experienced foreign companies on the domestic market in the field of technical regulation. The insufficient institutional, informational, organisational, managerial and personnel readiness of enterprises creates an urgent need for information and awareness campaigns, advisory services and the expansion of the network of certification bodies and

laboratories for product conformity assessment. Addressing these challenges in the methodological basis of consumer safety research will be supported by the development of a «roadmap» for domestic manufacturers to obtain CE marking.

The Treaty on the Functioning of the European Union also contains a separate section on environmental policy – Chapter XX. Article 191 (1) of the Treaty stipulates that the EU should promote: the preservation, protection and improvement of the quality of the environment; the protection of human health; the rational and sustainable use of natural resources; and the fight against climate change. The following principles apply to the achievement of these objectives: measures should be taken on the basis of the highest level of protection, taking into account the diversity of situations in different regions of the EU; the precautionary principle; preventive measures; environmental damage should be rectified at source; the polluter should pay. Article 191 (2) of the Treaty aims to promote the highest level of environmental protection, which is to be facilitated by EU environmental policy. In ensuring a high level of environmental protection, the local situation in the various EU Member States must be taken into account. EU environmental policy is based on the principles of precaution, non-damage to the environment, preventive action, rectification of damage and compensation for damage caused to the environment.

The objectives of harmonising legislative and regulatory documents include: transition to the principles of a ‘green’ economy (conducting environmental impact assessments, strategic environmental impact assessments, ensuring public access to environmental information); improving air quality, conducting air quality assessments and monitoring; introducing an integrated system of permits for emissions (discharges) of pollutants into the air, water resources and soil; rational management of water resources, including the marine environment; waste prevention and transition to a circular economy, rational waste and resource management (landfilling, management of mining waste, hazardous waste, etc.); protection of flora and fauna, natural habitats, etc.

Progress in fulfilling commitments under the «Pulse Agreement» system: approval of the key principles (strategy) of Ukraine’s state environmental policy for the period up to 2030, aimed at improving environmental standards and creating a safer level of environmental conditions for ecosystems and the population in line with European requirements; adoption of Ukrainian laws «On Environmental Impact Assessment» and «On Strategic Environmental Impact Assessment» with the aim of integrating environmental requirements into decision-making processes relating to business activities; creation of a unified environmental impact assessment register for the purpose of collecting, reproducing and providing access to up-to-date information on environmental impact assessment procedures to all interested parties; approval of concepts for the creation of a nationwide automated system «Open Environment», etc. Opportunities and next steps: achieving

high air quality indicators by reducing emissions from large combustion plants, using the best available technologies and management methods; reducing greenhouse gas emissions, gradually moving towards low-carbon economic development, which will contribute to the preservation of the ozone layer; ensuring the preservation of natural ecosystems in the regions, which will, among other things, increase their tourist attractiveness, and preserving natural habitats and natural fauna and flora in Ukraine.

The process of European integration must take into account the EU's climate goals, which will contribute to the joint effort to create a climate-neutral European continent in line with the Paris Agreement, the UN's 2030 Sustainable Development Goals and the Association Agreement between Ukraine and the EU. However, there are concerns that many measures in the proposed EU 'Fit for 55' package could be used for hidden protectionism, which could harm Ukrainian producers and be contrary to the objectives of the Association Agreement. The initiative on the carbon adjustment mechanism will result in the imposition of tariffs on goods originating in Ukraine, despite Ukraine's obligations to implement EU environmental standards under the Association Agreement. It is also recognised that the strategy on the use of fertilisers and pesticides requires a more balanced approach to ensure the efficiency of production processes and to avoid disrupting the supply of agricultural products in the EU and worldwide.

In the field of environmental protection, Ukraine needs to: attract financial resources to start the systematic development of a network of air quality monitoring stations; obtain support under the CASE project to create a joint Ukrainian-European analytical centre for the Ukrainian Climate Fund; ensure Ukraine's participation in the Life programme for nature reserves; ensure access to EU instruments and funds in areas that support decarbonisation, with a view to joining the EU's European Green Deal initiative, initially for cross-border projects; Formalise high-level dialogue between Ukraine and the EU on Ukraine's participation in the implementation of the European Green Deal and ensure Ukraine's accession to the EU Civil Protection Mechanism with a view to integrating Ukraine's national civil protection system into the European system for emergency prevention and response. In the field of standardisation, metrology and certification, priorities should be introduced, including: digital Europe, new technologies (artificial intelligence, Internet of Things and 5G), blockchain and DLT, innovation in cybersecurity, standards appropriate to the digital era and the provisions of 'Green Europe', etc.

The main content and obligations of Ukraine in the field of environmental protection and sustainable use of agricultural land include supporting and encouraging trade and foreign direct investment in eco- and goods, services and technologies, the use of balanced renewable energy sources and energy-efficient products and services, as well as the eco-labelling of goods. In addition, the Association Agreement (Article 360, Chapter 6 'Environment') provides for the

development and strengthening of cooperation on environmental protection issues and the promotion of long-term sustainable development and green economy objectives.

In order to ensure a high level of protection of human life and health, food law in Ukraine should, after harmonisation, be based on a risk analysis system. Food safety and quality legislation in Ukraine is governed by several legal acts, the most important of which are the Law of Ukraine «On Food Safety and Quality» and the Law of Ukraine «On Basic Principles and Requirements for Food Safety and Quality», based on the principles and requirements for food safety applied in the EU.

This legislation regulates relations between government authorities, producers, sellers (suppliers) and consumers of food products. It also establishes procedures to ensure the safety and quality of food products that are produced, distributed, imported or exported. In Ukraine, the state, through the relevant authorities, sets rules for the conduct of businesses, coordinates technical requirements for products and controls product quality. In the EU, however, the approach is different: the state only sets product safety parameters and monitors compliance, while all other functions are delegated to market participants. Consumer associations, producer associations and other entities are actively involved in the development of most standards. Market competition and consumer awareness require producers to ensure and continuously improve product quality.

Ukraine's integration into the global economic community should be accompanied by appropriate legislative changes, particularly in the area of food safety and quality. One of the key advantages of the law is the introduction of the European model of food safety in Ukraine, based on the 'farm to fork' principle. The frequency of state controls will be based on a risk-based approach. In addition, there will be an obligation to implement continuous procedures based on the Hazard Analysis and Critical Control Point (HACCP) system. This policy was based on the principles set out in the Green Paper on Integrated Product Policy, which aims to promote the development of the market for environmentally friendly products and public debate on this issue.

As with integrated product policy, the product life cycle is also relevant in ISO 14006:2011 standards, including consideration of the minimum environmental impact in the manufacture, design and promotion of products. The eco-design process should be based on life cycle thinking, ensuring that significant environmental aspects are taken into account at all stages of the product life cycle. Key elements of life cycle thinking include , setting targets to minimise the overall adverse environmental impact of a product, and taking into account the interconnections between environmental aspects and different stages of the life cycle.

Key areas for adapting legislation in the field of environmental protection and rational land use, together with the production of environmentally friendly products and the provision of high-quality services, therefore include a proposal to use the experience of developing regulatory

documents in technical committees such as the Scientific Research Institute of Standardisation of the State Enterprise «Ukrndnts», the leading organisation of the Ukrainian Ministry of Economic Development and Trade, responsible for standardisation, certification and quality, and for shaping state policy in these areas.

A significant part of the EU's environmental legislation takes the form of directives. EU directives aim to harmonise the national legislation of Member States with the requirements of EU law. The objectives set out in a directive must be achieved by Member States within a certain time frame. The objective set out in the directive is mandatory, but the means of achieving it may vary from country to country. EU directives ensure a common approach by Member States to cross-border environmental issues.

1.3. Prospects and applied issues of Ukraine-EU integration in the field of agricultural nature management

The European Green Deal defines EU policy for the coming years in areas such as climate, energy, biodiversity, industrial policy, trade and others. The transformation of Europe into the world's first climate-neutral continent by 2050 is to be achieved by stimulating economic development, improving people's health and quality of life, and turning climate and environmental challenges into opportunities in all EU spheres and policies, thereby ensuring a fair and inclusive green transition. The European Green Deal outlines how to make Europe the first climate-neutral continent by 2050. It sets out a new, sustainable and comprehensive growth strategy that will contribute to economic development, improve health and quality of life, and stabilise ecosystems. The Climate Law sets the goal of achieving EU climate neutrality by 2050 (a 50% reduction in greenhouse gas emissions compared to 1990 levels). According to Eurostat, EU agriculture is the only sector in the world to have reduced its greenhouse gas emissions (by 20% since 1990, from 543.25 million gigatonnes of CO₂ equivalent in 1990 to 438.99 million gigatonnes in 2017).

Ukraine shares the EU's climate policy goals. The key objective of the country's climate policy is to reduce greenhouse gas emissions by 65% by 2030, with a plan to achieve climate neutrality by 2060 at the latest.

In the agricultural sector, one of the directions of the Green Deal is the implementation of the 'farm to fork' strategy, which represents a new approach to ensuring that agriculture, fisheries, aquaculture and food production and supply chains contribute appropriately to this process. The 'farm to fork' strategy comprehensively addresses the challenges of sustainable food systems and recognises the inextricable link between human health, a healthy society and a healthy planet. The transition to a sustainable food system can bring environmental, health and social benefits and

offer economic advantages for businesses. The Farm to Fork Strategy is a new comprehensive approach to agribusiness that provides opportunities to improve lifestyles, health and ecosystems.

However, even within the EU, this path is not the same in all Member States. In addition, food production, processing, retail, packaging and transport contribute significantly to air, soil and water pollution, while greenhouse gas emissions have a significant impact on biodiversity. Therefore, despite the fact that the EU's transition to sustainable food systems has already begun in many areas, food systems remain one of the key drivers of climate change and ecosystem degradation. There is an urgent need to reduce dependence on pesticides and antimicrobials, increase organic farming, improve animal welfare and restore biodiversity losses. The transition to sustainable food systems will ensure the resilience of agribusiness and its brands, thereby guaranteeing the future of the EU food chain.

In view of this, global trends in the development of the agricultural sector that pose a number of challenges for Ukraine in the medium term (in peacetime) include:

- increasing global resource imbalances, particularly food shortages, which will stimulate price growth in agricultural and food production;
- the high investment attractiveness of agricultural production will increase competition between countries with similar significant agricultural potential to Ukraine;
- the need to modernise and digitise key assets;
- uneven global development of agricultural production (due to high subsidies in developed countries and varying levels of investment), distortion of competition due to protectionist measures, and the growing gap between developing countries and global leaders.
- globalisation of the processing industry and relocation of production (especially in labour-intensive sectors) from developed to developing countries.

In accordance with the Association Agreement between the EU and Ukraine, Ukraine is harmonising its existing directives and legislative and regulatory documents, making innovative EU solutions a reference point for the adaptation of legal standards. Specifically:

- reducing the environmental and climate impact of the EU food system;
- strengthening soil resilience;
- ensuring food security in the context of climate change;
- global transition to a 'farm-to-fork' approach to agribusiness and other measures.

For Ukraine, European integration will involve:

- ensuring that the food chain, which includes food production, transport, distribution, marketing and consumption, has a neutral or positive impact on ecosystems, preserving and restoring the terrestrial, freshwater and marine resources on which the food system depends;

- contributing to climate change mitigation and adaptation;
- protection of soil, water, air and plant health, among other things;
- ensuring food security, nutrition and public health;
- providing access for all to sufficient, high-quality food and sustainable food systems that meet high standards of safety and quality, plant health and animal welfare, while respecting dietary needs and food preferences;
- generating fair economic returns in the supply chain, ensuring that the most sustainable food is the most affordable, strengthening the competitiveness of the EU supply sector, promoting fair trade, creating new business opportunities while maintaining the integrity of the single market and occupational health and safety.

These and other aspects of European integration are being implemented in Ukraine. However, it is characteristic that EU directives and standards are constantly evolving (improving), and Ukraine must regularly adjust its procedures for adapting and implementing legislative and regulatory documents.

An example of systematic innovation is the acceleration and facilitation of the transition to ensure greater sustainability of all food products on the EU market by the end of 2023. The EU is considering a legislative proposal for a framework for a sustainable food system. This will strengthen policy coherence at both national and EU level, promote sustainability in all food-related policies and areas, and strengthen the resilience of food systems. Each EU country has a strategic plan for the Common Agricultural Policy (CAP). It is well known that the CAP in the EU is focused on the European Green Deal. The new agricultural policy aims to help farmers improve their environmental and climate performance through a results-oriented model, better use of data and analysis, improved mandatory environmental standards, new voluntary measures and a greater focus on investment in green and digital technologies and practices [22, 23].

A sustainable food system must ensure a sufficient and diverse supply of safe, nutritious and affordable food in all circumstances. Events affecting the sustainability of food systems do not necessarily originate in the food chain itself, but can be triggered by political, economic, environmental or health crises. The EU is therefore assessing the resilience of the food system and improving contingency plans to ensure food supply and food security. A global trend, to which legislative and regulatory documents are adapting, is the concept of availability and accessibility of organic, environmentally friendly and sustainable food products with the aim of reducing the overall ecological footprint. To support this trend, the EU uses a Code of Conduct for Responsible Commercial and Marketing Practices, which is accompanied by monitoring. Such approaches have potential in Ukraine and require practical application and discussion in scientific circles.

Ukraine must therefore take concrete measures in the areas of health protection and socio-ecological-economic development, focusing on the following areas:

- production of food products in accordance with balanced management of agricultural resources;
- reducing the water and soil footprint and overall environmental impact;
- reducing energy consumption by increasing energy efficiency;
- increasing land use efficiency through the computerisation and automation of all types of agricultural production;
- adapting marketing and advertising strategies to the needs of vulnerable population groups;
- ensuring that product pricing campaigns do not reduce citizens' perception of the value of food;
- reducing the use of packaging.

At the same time, Ukraine must introduce measures to expand and promote sustainable and socially responsible production methods and circular business models in the food industry and retail, especially for small and medium-sized enterprises, in conjunction with initiatives in the field of digitalisation in agribusiness [24].

Recent years have confirmed the importance of innovative approaches to food packaging, which plays a key role in the sustainability of food systems. Legislation on materials that come into contact with food needs to be revised in order to improve food safety and protect public health (in particular, to reduce the use of hazardous chemicals). Start-ups and entrepreneurial projects are currently promoting the use of innovative and sustainable packaging solutions that use eco-friendly, reusable and recycled materials, which will help to reduce food waste. Packaging manufacturers have already introduced basic requirements for eco-friendly production [25, 26].

The EU is constantly improving marketing standards to ensure packaging recycling while strengthening the role of sustainability criteria (storage and potential food losses during logistics). In parallel, developments are underway in the area of geographical indications to include sustainability criteria.

In addition, in order to strengthen the sustainability of regional and local food systems and create shorter supply chains, the EU is promoting a reduction in dependence on long-distance transport (e.g. in 2017, approximately 1.3 billion tonnes of primary agricultural, forestry and fishery products were transported by road). These scientific developments have their own history in Ukraine in terms of regional food self-sufficiency [27, 28].

EU plans for soil protection and production also include acquiring new knowledge and developing agroecological approaches in primary production, as outlined in FAO reports on agroecology [29-32]. The EU is continuously updating databases on innovation in agriculture and its sustainability with a view to implementing the ‘farm to fork’ strategy. This information activity will improve the performance of agricultural holdings at regional, national or sectoral level. Through specialised advisory services, farmers will receive feedback and recommendations that link their experiences to European innovation partnerships and research projects.

The common European information space for agriculture will thus strengthen the competitive sustainability of EU agriculture by processing and analysing data on production, land use, environmental aspects and other factors, enabling accurate and specific approaches to production at farm level and monitoring the efficiency of agri-business activities and land use.

The implementation of the Common Agricultural Policy and the UN Green Deal require a global transition to sustainable agri-food systems and, consequently, the achievement of sustainable development goals, as announced globally by the UN, FAO, ISO and other organisations. Through its foreign policy, including international cooperation and trade policy, the EU supports the development of a circular and green economy in the area of sustainable food systems with all its partners in bilateral, regional and multilateral forums.

Harmonising legislative and regulatory documents in Ukraine therefore requires constant monitoring of innovations in the EU and around the world to ensure the most effective implementation procedures in our country. European countries promote international standards in regional programmes and Community legislation to support the production of organic agri-food products that meet high standards of safety and sustainability.

When harmonising legislation in Ukraine, particular attention should be paid to promoting individualised approaches to production in the agricultural sector (support for small farmers, cooperative standards, regional trademarks, digitisation of land use, etc.). Another issue of harmonisation is the reduction of food waste and losses throughout the entire food production life cycle.

One of the constantly evolving areas in the EU is international cooperation and research in the field of food production, with a particular focus on adapting to climate change and mitigating its impact on land use, production and supply chains, nutrition and the prevention of food crises, food safety standards, such as the development of innovation through agricultural research (DESIRA initiative), and the integration of the common agricultural policy into all areas of the economy.

Another important aspect of the agricultural sector and harmonisation is that the EU is constantly developing new approaches to sustainable food systems, which requires Ukraine to

continuously work on introducing best practices and good rules in the agricultural sector. For example, in order to facilitate the gradual transition to safer plant protection products, the EU is considering, in accordance with WTO rules, a revision of import tolerances for substances that pose a high risk to human health (these substances may have an impact on human health and include substances classified as mutagenic, carcinogenic, toxic to reproduction or substances with endocrine-disrupting properties, as defined in points 3.6.2 to 3.6.5 and 3.8.2 of Annex II to Regulation (EU) № 1107/2009).

When it comes to harmonising regulatory documents, Ukraine needs to clearly set priorities and implement them when adapting legal documents. The EU's vision includes working with trading partners and developing countries to support the transition to more sustainable use of different types of fertilisers, plant protection products, etc.

European agricultural policy and the Green Deal generally align the food system with food security needs at various levels and respond positively to the ambitions of economically developed countries in the area of environmentally sustainable goods and services. The aim of this methodology is to transform the EU food system into a global standard for sustainability. The transition to sustainable food systems therefore requires a collective approach involving public authorities at all levels of government, including businesses, government agencies, communities, private sector entities within production and supply chains, non-governmental organisations, scientists and citizens. Under these conditions, Ukraine should cooperate at various levels and participate in broad discussions on the formation of sustainable food policy, including national, regional and local measures, as emphasised in scientific publications [33].

One of the key advantages of Ukrainian legislation is the implementation of the European model of food safety based on the «farm to fork» principle. In addition, control functions in Ukraine are entrusted to a single state body responsible for the entire food chain, including animal health and welfare, veterinary medicine, animal identification and registration, food and feed safety, plant health and protection, and animal by-products. The frequency of state inspections will be based on a risk-oriented approach. There is also an obligation to implement permanent procedures in establishments based on the principles of the Hazard Analysis and Critical Control Point (HACCP) system.

The adoption of the EU's conceptual approach to technical norms and standards, which forms the basis for the functioning of the Community's single market, is a valuable experience for Ukraine. EU technical norms and standards set out the basic requirements and criteria for assessing goods, services and processes. Standards ensure that goods and services are compatible with their intended purpose, as well as with human health, safety and the environment. EU requirements for quality, safety, the environment and other product requirements are among the highest in the world.

The removal of barriers to the movement of goods caused by different technical norms and standards in Member States is ensured in two ways: by harmonising national standards through the adoption and implementation of uniform legal norms in this area, and by applying the principle of mutual recognition. Currently, the EU uses the Council Resolution on a new approach to technical harmonisation and standardisation.

Environmental protection policy is also integrated into EU activities. This is currently reflected in the «Integrated Approach to Product Policy – Building on Life Cycle Thinking». This policy is based on the provisions of the Green Paper on Integrated Product Policy, which aims to promote the development of the market for environmentally friendly products and stimulate public debate on this topic, as confirmed by publications [34].

The EU's experience in responsible soil protection is a key aspect of the safe use of agricultural land. Various EU policies contribute to soil protection, including environmental, water and agricultural policies. Agriculture can have a positive impact on soil condition through land management practices such as organic and integrated farming. Soil protection measures often focus on other environmental media or objectives and are not part of a coherent soil protection policy. The growing awareness of the importance of soil protection is reflected in the revision of the 2003 Council of Europe Charter on Soil Protection.

The overall objective is to protect and sustainably use land based on the following key principles: preventing further land degradation and maintaining its functions; restoring degraded land to a level of functionality that meets at least current and projected uses, taking into account, among other things, the costs of restoration. Ukraine therefore needs measures at local, national and European level. Inadequate soil protection will undermine Ukraine's sustainability and long-term competitiveness.

'Food security' is therefore understood as the state of the economy of a community (administrative region, state) in which the population is guaranteed physical and economic access to high-quality and safe primary food products in quantities that are not less than those corresponding to rational dietary standards, provided that agricultural resources are used rationally.

In order to ensure food security, harmonise legislative and regulatory documents and strengthen the potential of agribusiness, the following issues need to be addressed:

- ukrainian agro-industrial production as a type of economic activity has not received quality incentives for the growth of small and medium-sized enterprises due to the inefficiency of agriculture, the absence of a unified state policy over the last 30 years and the lack of support programmes.

- the structure of agricultural production requires planning and a stronger role for regional state policies to support livestock farming, fisheries and beekeeping in small agricultural enterprises (which grow almost 90% of vegetables and potatoes, 69% of cattle and 55% of pigs);
- slow introduction of new production equipment, decline in domestic production of agricultural machinery and reduced use of organic and mineral fertilisers on crops;
- unresolved environmental issues of land use and responsibility for reducing soil fertility;
- underdeveloped infrastructure for the purchase and sale of agricultural products;
- low economic efficiency of agricultural land use;
- high interest rates on bank loans;
- insufficient organisational and financial support for state purchases of basic food products;
- lack of long-term livestock breeding programmes with adequate funding and implementation;
- absence of a transparent and holistic market for agricultural and food products;
- low level of investment in the agricultural sector and non-compliance of domestic products with international quality and hygiene standards;
- high technogenic and anthropogenic pressure on the soil, aggravated by natural factors;
- high utilisation of agricultural land and incomplete land reform;
- threats to food security include insufficient food consumption by the population, large differences in costs between social groups, and dependence on imports of certain products;
- the raw material nature of agricultural and food exports;
- rising prices of agricultural products on the domestic market;
- slow adoption of international standards and food quality systems.

As a result of implementing an extensive development model in the agricultural sector, most of the country's food security indicators exceed the threshold values. Global and national trends in the development of agricultural and food markets determine the need to accelerate reform processes in Ukraine's agricultural sector, harmonise legislative and regulatory documents and implement state policies aimed at stabilising the domestic market for agricultural and food products and exploiting the potential benefits of Ukraine's increased presence in global food markets, among other measures. Innovative approaches to harmonising regulatory documents in the area of food safety should also include:

- an economic mechanism that includes measures to stimulate the economy and adapt agricultural and food production to the conditions of globalisation and specialisation (Fig. 1.5);

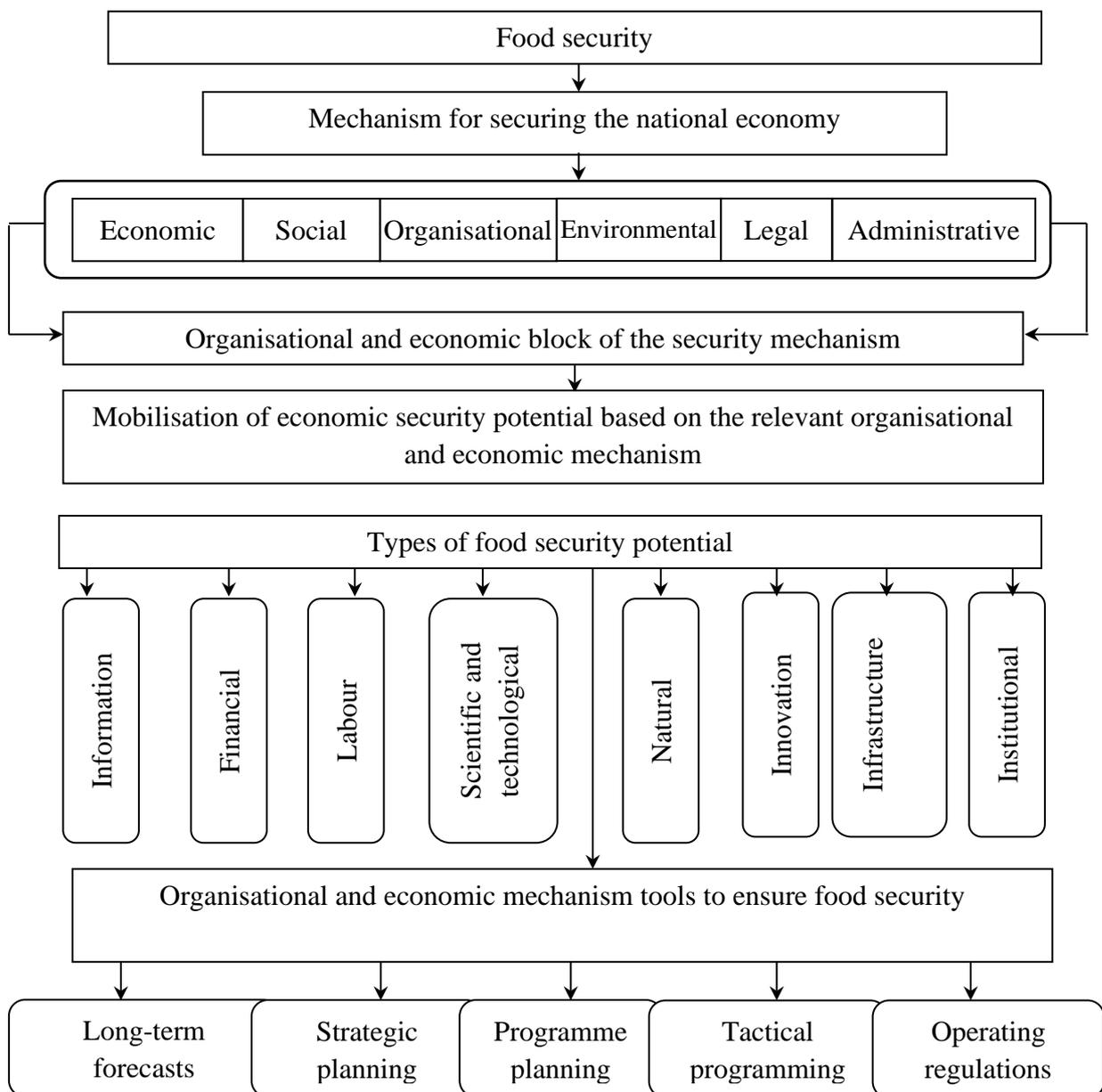


Fig. 1.5. Conceptual approach to creating an organisational and economic mechanism for food security in the socio-economic system at the national level

– an information mechanism through appropriate systems for gathering and analysing information, interaction between all participants in the development and implementation of food security policy, coordination and control of the activities of regulatory authorities, and consolidation of all participants in the field of food security;

– a social mechanism for implementing food security as socio-economic processes in their own development.

– innovations relating to safety issues in the use of agricultural resources during the adaptation, harmonisation and implementation of national legislative and regulatory documents in order to meet European Union requirements should therefore include:

- taking into account opportunities for diversification of the national economy and the requirements of the international division of labour;
- the greening and socialisation of all economic factors in the production of goods and provision of services;
- developing production potential;
- control of product quality, production costs and prices;
- cooperation and regionalisation of agricultural enterprises in relation to the specific characteristics of soil, water and climate;
- development of own standards for communities and businesses with protected geographical indications, among other things.

The future of the agricultural sector therefore lies in diversifying production development by increasing the capitalisation and investment attractiveness of agricultural enterprises through the introduction of a land market, support for family farming activities and the introduction of modern, adaptive, environmentally safe production technologies. The most optimal approach for the agricultural sector would therefore be a comprehensive European integration programme that would ensure consistent administrative stimulation of reforms and, at the same time, restructuring and reduction of bureaucratic structures.

PART 2. INNOVATIVE PRINCIPLES FOR CREATING ECOLOGICAL AND ECONOMIC SECURITY IN THE USE OF AGRICULTURAL LAND

Over the past 50 years, global food production has increased by approximately 300% thanks to humanity's remarkable ability to innovate. However, the global community continues to lose more than a third of all food produced, with losses exceeding \$900 billion annually. The global smart agriculture market was estimated to be worth \$15.3 billion in 2020 and is expected to reach \$22.5 billion by 2026. According to the latest estimates, global food demand will surge by 70% by 2050, requiring approximately \$80 billion in investment in agriculture to feed an estimated nine billion people [35].

Significant demand for agricultural products, driven by population growth, leads to higher costs for fertilisers, pesticides, herbicides and other agricultural resources. In addition, the greenhouse effect and subsequent global warming are causing severe droughts and soil degradation. All of this makes precision agriculture critically important for the sustainable development of humanity. In a broader sense, agrotechnologies are designed to increase the productivity and profitability of farms by reducing costs or crop losses.

If there is no proper link between land use regulation and water use regulation, changes in land ownership and land use rights in one place can affect water access rights in another place, which has implications for agriculture. In order to help producers make decisions on optimising water use and to increase consumer awareness and influence their choices, various water accounting systems (life cycle analysis, 'water footprint', etc.) have been proposed. However, this tool should be used on the basis of scientific justification, as it does not always reflect all the details of a particular situation, in particular the scarcity of water resources at local level and its impact on ecosystems. In many cases, national water resource policies do not prioritise water use in the context of food security. Although water resources are sometimes prioritised for food security purposes, the problem lies in the practical implementation of this provision, mainly due to the lack of a comprehensive decision-making process, with decisions on irrigation, industrial development or energy being taken by different authorities without considering their cumulative impact on water resources. These problems are compounded by the challenge of ensuring safe drinking water and sanitation.

The world is therefore increasingly aware that complex, multifaceted issues, including food security and nutrition, require a holistic, cross-sectoral approach that combines the resources, knowledge and expertise of various stakeholders. The 2030 Agenda for Sustainable Development offers the means to achieve these goals. In particular, it involves strengthening global partnerships for sustainable development; stimulating and supporting effective partnerships between state organisations and the private sector, as well as between civil society organisations, etc. [36].

Therefore, the implementation of a consistent state policy focused on a European and Euro-Atlantic course, the development of relations with new Asian and Middle Eastern centres of gravity, the creation of a favourable business environment, the development of entrepreneurship and export promotion, the attraction of investment and the development of capital markets, increasing domestic consumption and other mechanisms will strengthen the country's position as a regional player and become factors of economic growth. Ensuring innovative, anticipatory economic growth will contribute to the development of the national economy through the appropriate quality of education, science, medicine, culture and the preservation of natural ecosystems in the context of the green economy [37, 38].

To address these challenges, the concept of ecological and economic security in the use of agricultural natural resources (CEANRU) was developed. Its goal is to find ways to reform the Ukrainian economy to make it socially responsible, ecologically safe, and economically viable, which requires the implementation of ecologisation, digitalisation, socialisation and economic justification through a system of different levels of management, from the global level to the level of small farmers and individuals (people as users of natural resources, as members of a community defined by a specific territory); introduce mechanisms for the intellectualisation of natural resource use and the implementation of a project-based approach to the activities of each community in order to ensure the efficient use of resources and increase budget revenues, ensure livelihood security and, as a result, their natural capital (Fig. 2.1).

The CEANRU concept should be understood as: a mechanism for ensuring ecological security in all types of natural resource use, including agriculture, for the general public who use natural resources; a practical tool for regulating eco-economic relations at both the macro and micro levels; a system of criteria for the macroeconomic evaluation of natural resources (from the state to the community level), specifically with regard to the characteristics of reproduction and systematics in natural resource management, tools for different types of management, etc. (Fig. 2.2).

The hypothesis in the concept focuses on the implementation of sustainable food systems, which are the basis of the 2030 Agenda for Sustainable Development. Accordingly, in order to achieve the sustainable development goals, it is necessary to change the global food system to make it more productive, more inclusive of a larger number of population groups, environmentally and economically sustainable, and capable of producing safe food for all. These are complex and systemic challenges that require a combination of interconnected measures at local, national, regional and global levels [39].

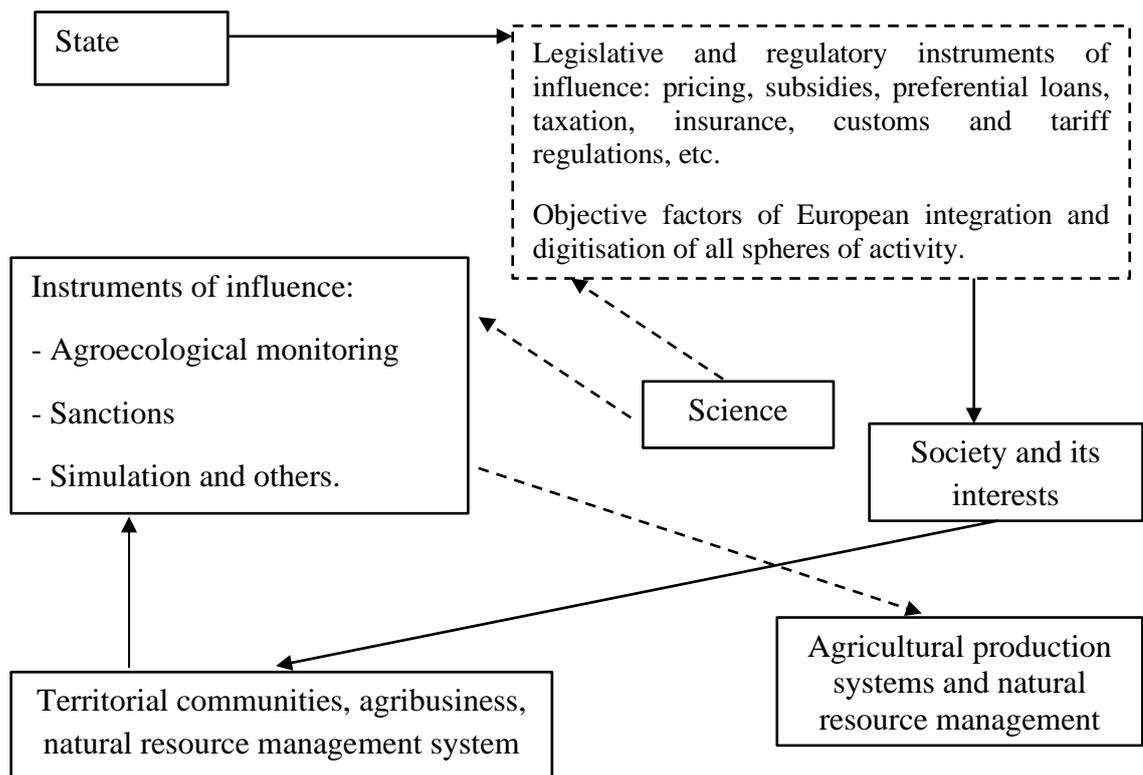


Fig. 2.1. The place of the concept of ecological and economic security in the use of agricultural natural resources in society

The concept of ecological and economic security in the use of natural resources in agriculture includes a life cycle analysis method developed to optimise industrial processes and related goods.

Several important initiatives have been launched recently, such as the «life cycle» and the development of ISO standards, which aim to establish uniform principles and methodologies to facilitate the reporting of water and land footprints during life cycle analysis for businesses. As a result of these efforts, methods for comprehensive water consumption accounting for impact analysis have been developed (Berger and Finkbeiner, 2010), and ISO 14046 was published in 2014. Water footprint analysis and life cycle analysis share the common goal of assessing the impact of water consumption on natural resource systems. However, there are significant methodological differences between the two approaches (Boulay et al., 2013), such as the inclusion of green water in water footprint analysis, whereas the ‘life cycle’ does not take it into account. There are also differences in the way water pollution is taken into account [40, 41].

Currently, there are two main concepts of regional development in terms of environmental issues that have emerged: the technogenic (resource) and biospheric concepts (Korobkin, Peredilsky, 2003), ecological certification of natural resource systems (Skrypchuk, 2011), assessment of the ecological safety of individual regions and industrial sectors (Redkozubova S.A., Stepanova A.V. (2001), Myshko F.G. (2003)), ecological safety criteria for specific regions and

industrial sectors, and assessment of damage caused by pollution of natural resource systems (Ishalin et al., 2004, Petrov, 2004), informational publications, etc. [42–44]. According to these development trends, the solution to ecological problems lies in assessing the pollution of natural resource systems, developing standards for permissible levels of pollution (including percentiles) of natural resource systems, and introducing resource-saving technologies.

The formulation of the concept of ecological and economic security in the use of natural resources in agriculture should be carried out at global, regional, local and point levels. The local level should be studied to ensure that its indicators serve as baseline data for assessing security only at the regional level. A number of different indicators (sanitary-toxicological, ecological, sociological, demographic, medical, etc.) should be taken into account for the quantitative measurement of the security of natural resource use in agriculture in a territory (community).

The development of the concept of ecological safety in the use of agricultural natural resources is based on the idea of preventing and compensating for damage caused by the natural resource system to human health and citizens' property as a result of pollution, damage, irrational use of natural resources, destruction of natural ecosystems and other violations, as well as on the concept of ecological certification of territories, etc.

The concept takes into account the state programme for the adaptation of Ukrainian legislation to that of the European Union and Ukraine's acceptance as a candidate country for EU membership. Such decisions are reflected in the hypotheses, practical proposals and development of new regulatory acts of Ukraine, created in accordance with EU legislation. Specifically, the economies of developed countries take into account the concepts of «natural capital», «green» economy, environmental audit and management, safety and use of agricultural natural resources as economic categories.

Ecological security is therefore a set of conditions, processes and activities that ensure ecological balance in natural resource systems and do not lead to loss of life (or threats of such loss) caused by the system and humans. It is also the process of ensuring the protection of the vital interests of individuals, society, nature, the state and humanity as a whole from actual or potential threats caused by anthropogenic or natural impacts on natural resource systems.

The KBA system is a set of legislative, social and management measures aimed at maintaining a balance between natural resource systems and anthropogenic pressures. KBA is achieved through a system of measures (forecasting, planning, proactive preparation and implementation of a set of preventive measures) that ensure a minimum level of adverse effects of natural and technological processes on human life and health while maintaining an adequate level of industrial, communication and agricultural development. The KBA system is a mechanism that

ensures acceptable negative impacts of natural and anthropogenic factors of ecological threat on natural resource systems and people.

Key principles of the approach to assessing the sustainability (safety of use of agricultural natural resources) of natural resource systems:

- Priority of scientific support in organising ecologically balanced use of natural resources.

- Systematic and universal approaches to assessing technogenic changes in natural resource systems in different natural conditions and production specialisations.

- System analysis of the possible role of known physical, chemical, microbiological and geodynamic factors of technogenic origin on the main spheres of the Earth and their main components (use of percentiles).

- Use of individually determined maximum permissible concentrations (MPC) of chemical substances and their percentiles, taking into account the probability of a sharp increase in their overall toxic potential (bioindication, expert opinions).

- People and their activities, as well as society, are prototypes of objects and phenomena in the outside world.

- A study of the impact of new technologies on natural resource systems should be carried out prior to their implementation (i.e. their impact should be thoroughly investigated).

- Economic growth is a measure of economic and social progress in communities (individual territories). However, the growth of gross national product, with an assessment of factors destroying natural resource systems (natural capital), is considered an indicator of the success of society.

The aim of this concept is to systematically take into account the state of natural resource systems and their potential as an integral part of the economic, ecological and social security of the state and individual territories (e.g. communities). This is done with the aim of improving the quality of life of the population and ensuring balanced economic growth in the country. It also includes theoretical, methodological and practical socio-ecological-economic justification for ensuring the security of natural resource use in agriculture, optimising the use of water and soil resources (e.g. the water and soil footprint of traditional, intensive and organic farming practices) and justifying the areas under energy crops in different regions as factors threatening the country's economy and natural resource systems according to global standards.

In the context of achieving the economic vision, the mission of this concept is to create opportunities for implementing the safe use of agricultural natural resources in order to ensure an adequate level of well-being and the preservation of natural resource systems as renewable

resources in Ukraine. This will be achieved through innovative and anticipatory economic growth, taking into account the latest global decisions on the «green» economy and the need for climate neutrality.

The concept also aims to create opportunities at all levels of government to ensure the safe use of agricultural natural resources, guarantee an adequate level of well-being, and preserve natural resource systems as renewable resources in Ukraine. The concept envisages the gradual achievement of this goal with a view to increasing the well-being of the population and promoting the rational use of natural resources. The first step is to create competitive conditions for business and investment based on digitalisation and innovation.

The concept includes the economic development of local communities aimed at increasing their food security, providing the population with food, raw materials for industry, a high-quality environment and natural resources in sufficient quantity and quality. It also emphasises the assessment of the ecosystem functions of natural resource systems and the preservation of natural capital. Taking these ecosystem functions into account will contribute to filling local budgets, including through the development of sustainable green tourism, the creation of a positive image and the promotion of the brand of specific territories.

The research problem is the need to develop a concept of ecological and economic security for scientific-methodological, resource and socio-ecological-economic justification of systematic management of natural resources and ecological-economic security in the use of soil and water resources in accordance with European directives and global standards, using information systems and global socio-ecological-economic processes.

Methods, principles and values: In order to achieve the necessary transformations in food systems to ensure global food security, changes need to be coordinated and implemented in a comprehensive manner. These changes should be implemented on both a small and large scale, with structural and regulatory adjustments being made at a higher level. Food systems operate in different ecological, socio-cultural and economic conditions and face different challenges.

Therefore, users of agricultural natural resources must work in ways that take into account the specifics of external conditions and transitional practices adapted to sustainable food systems and natural resource management as a whole. The three interrelated principles that broadly define the direction of the transition to KBAP are: improving resource efficiency; strengthening resilience to external influences; and ensuring social justice and accountability. These principles aim to ensure the rational use of production resources, including those that are scarce, adaptation to climate change and a more comprehensive consideration of the social aspects of food systems.

Methods for ensuring KBAP are divided into groups:

1. Methods for assessing the quality of natural resource systems:

– Measurement methods – quantitative, the results of which are expressed by specific numerical parameters (e.g. physical, chemical, optical, etc.).

– Biological methods – qualitative (the result is expressed verbally, e.g. using terms such as «many-few», «often-rarely», etc.) or partially quantitative.

2. Modelling and forecasting methods, including system analysis, system dynamics, informatics, correlation-regression analysis, statistics, etc.

3. Combined methods (physical-chemical, biological, percentiles of substances in natural resource system objects, etc.).

4. Methods of quality management of natural resource systems (ecological-economic mechanisms and tools).

5. Administrative methods of state regulation restrict the activities of producers through legal means, forcing them to abandon the production of environmentally harmful goods (services) in favour of environmentally oriented or at least environmentally acceptable ones.

6. Social methods aimed at stimulating the production of environmentally friendly goods (provision of environmental services) by creating conditions leading to more efficient use of resources and cleaner production through environmental education, advertising, etc.

7. Economic methods aimed at creating material incentives for the production of environmentally friendly goods (services). Under current economic conditions and existing environmental problems, special attention should be paid to economic methods of state regulation based on incentives. In this context, competition between producers for subsidies, benefits, loans, etc. is important.

8. Methods that prevent adverse anthropogenic impacts on the territory of a region (community) include regulating the behaviour of an object by changing the nature of its operation, avoiding situations that may damage ecosystems, and planning new enterprises.

9. Methods that reduce the likelihood of an adverse event include measuring the operating conditions of a facility without affecting its nature. For example, replacing production technologies with less harmful or environmentally safe ones.

10. Methods to strengthen the protection of natural resource systems and relevant facilities (tasks) in mechanisms to prevent the spread of adverse effects to other areas, communities, ecosystems, etc.

Methodologies should strike a balance between technical (scientific) accuracy on the one hand and the ability to present results clearly on the other, taking into account the availability of data. For example, integrated water and soil resource management will contribute to achieving social, environmental and economic objectives within a cross-sectoral approach.

In many countries, water consumer associations can play an important role in water resource management and water supply services, particularly at local level, including irrigation systems. The regulatory system should include mechanisms for resolving conflicts of interest and settling disputes fairly. Decentralised regulation allows for better consideration of user needs and resource conditions, and more active involvement of users, who are guaranteed rights and participate in resource management decision-making processes. Decentralised regulation often involves strengthening local organisations and/or creating specialised institutions such as water user associations or river basin organisations.

For example, the concepts of «water footprint» and «land footprint» are effective in raising awareness of the indirect consumption of water and land that is «absorbed» by goods. This method is mainly used to assess the consumption footprint of countries, regions and individuals, but it cannot take into account all the local specificities of water use in production zones, as this would require complete tracking from production to consumption.

A comprehensive ecological assessment of the safety of agricultural natural resource use for communities or regions therefore includes:

- Systemic assessment of natural resource systems and social factors.
- Determination of anthropogenic load.
- Zoning of the territory for tasks and corresponding indicators (using environmental audit procedures and data obtained).
- Identification of factors, sources and work priorities for economic activity based on the principles of the «green economy».
- Continuous monitoring (e.g. GIS): e.g. regulation of the impact on natural resource systems; control of resources affecting natural resource systems; quality control of natural resource system components.
- Decision-making: formulating socio-ecological-economic decisions; preventing the impact of anthropogenic factors on natural resource systems; minimising the consequences of natural ecological risks; developing and improving environmental legislation and methods for shaping an ecological worldview.

The concept defines the following principles and values in the socio-ecological-economic spheres of state activity:

- direction of movement («key guidelines») – European integration (implementation of the state's strategic course to obtain full EU membership);

- decarbonisation of the economy (increasing energy efficiency, developing renewable energy sources, developing the circular economy and synchronisation with the European Green Deal initiative);

- an efficient digital services state and compact state institutions (development of the digital agricultural economy as one of the drivers of Ukraine's economic growth);

- rule of law (inviolable private property, adherence to the principles of the rule of law in the implementation of state environmental policy in the use of all types of natural resources), [39];

- development of «green» business, innovation, digitalisation;

- institutional capacity («a state capable of ensuring development»);

- pragmatism, subjectivity in defining the directions of economic development;

- systemic economic approach, ability to effectively unify the needs and real possibilities of natural resource systems;

- implementation of the European Green Deal, including achieving climate neutrality by 2050. The action plan includes several key measures across all sectors of the economy, including: investing in environmentally safe technologies, supporting innovation in industry, introducing greener modes of transport, decarbonising the energy sector, ensuring greater energy efficiency in buildings, and working with international partners to improve global environmental standards;

- implementation of the interregional plan «From Farm to Fork Strategy», aimed at developing a fair, healthy and environmentally safe food system [45].

The values for implementing the concept at the international (global) level will be:

1. Understanding by national leadership and all levels of government of the need to strengthen the complex use of agricultural natural resources as a source of food and multisectoral benefits, including in the food, agriculture, health and education sectors.

2. Capacity development and knowledge exchange. Developing and improving capacity, as well as transferring knowledge to strengthen resilient natural and food systems.

3. Emergency preparedness and response: coordinated technical support is provided to countries to strengthen their preparedness and response to food system challenges caused by wars, disasters and emergencies [46].

The research methodology includes: setting research directions, namely:

1. Theoretical and methodological: summarising global experience, developing a conceptual framework, developing a strategy and an ecological-economic mechanism for its implementation, scientific-methodological, resource and socio-ecological-economic justifying processes ensuring ecological-economic security in the use of soil and water resources in accordance with European directives and global standards using information systems, including

the development of mechanisms and instruments for joint financing, solving problems of rational water and soil use using examples from enterprises and organisations.

According to the systematic method of researching domestic and global experience, directions for the use of Ukraine's natural capital were developed based on the systematisation of indicators of the socio-ecological and economic security of the state according to its structural elements and levels.

2. Methodological and organisational: development of methods for assessing and modelling the state and trends in the use of agricultural natural resources, environmental certification in the field of natural resource use, objects and territorial-economic systems (communities); methods for calculating payments for enterprises and organisations operating in specific territories; development of a legislative basis for the organisation and implementation of the concept; determination of the amount of benefits for investors and owners for environmentally safe activities, land use, ecological certification of products, services, agricultural land, forests, community territories, etc.

Use of general scientific and special methods, including: dialectical, abstract-logical – to generalise theoretical provisions and define the essence of socio-ecological and economic security of territorial communities; intellectualisation of the TG economy for their effective socio-economic development, preservation of natural capital, its sustainability and genetic information for current and future generations as an indisputable condition for supporting social life; system analysis – to create a general system of indicators of socio-ecological and economic security and its impact on the volumes and indicators of costs for the preservation and reproduction of natural capital.

3. Practical: development of organisational and economic tools and preferences for the proper environmentally safe use of agricultural natural resources on different categories of land and territories; information support for services and the production of ecological and environmentally safe products; development of scenarios to support the proper condition of certified territories and the development of ecological entrepreneurship; creation of an organisational mechanism for providing information to consumers and the public about the quality of natural resource systems and methods for their optimal use; organisation of an integrated monitoring system (based on GIS and IT systems).

The implementation of the strategy will yield fundamentally new results: methodology and practical scientific outputs for the use of EU directives and standards, best practices and cleaner technologies as tools for addressing environmental problems in Ukraine; tools to ensure the safe use of water and land based on the river basin principle; innovative tools for the development of ecological production in Ukraine in the context of transformation and European integration;

justification of methods and methodologies for assessing the efficiency of shared use of soil and water resources – the ‘water’ and ‘land’ footprint (for the first time); methodology for determining product prices with regard to the «water» and «land» footprint (for the first time); ecological and economic justification of losses resulting from an increase in the area of crops with high water consumption in modern agriculture focused on intensive production (for the first time); forecast of «virtual» water consumption and «land» footprint for scientifically justified, economically advantageous and ecologically optimal agricultural crops in Ukraine (for the first time); balancing domestic consumption, exports and imports of «virtual» water in Ukraine (for the first time); justifying the export of «virtual water» from Ukraine to ensure national security at the global level (for the first time).

These methodological development trends are based on a systemic approach in economics, ecology and the social sphere, take into account synergistic effects and are in line with the global level. The impact of the proposed concept can be assessed using a macroeconomic general equilibrium model (computable general equilibrium) [47]. When implementing KBAP, the following criteria must be taken into account: generating results at the macroeconomic level, the ability to quickly create scenarios and select the best option, taking into account initiatives from at least seven production sectors, a planning horizon of 5–7 years, the use of instruments such as private and public investment, direct and indirect tax rates, productivity increases, changes in production technology, etc. The strategy and methods of implementation consist in creating suitable conditions for economic development in line with the requirements of: European integration, ecological modernisation, taking into account Ukraine’s innovation and investment opportunities on the road out of the economic crisis, implementation of a unified policy in the field of metrological support, standardisation, certification and accreditation.

The state strategy for implementing the KBAP should be a systemic document that ensures not only the preservation but also the systematic reproduction of the main components of the ecological mechanism, such as the reproduction of ecological demand, the reproduction of an ecologically oriented production base and the reproduction of motives for greening, among other things. Under these conditions, the implementation of systemic innovation processes of ecological social and economic development is possible only if state authorities and their structural components are able to create reproduction mechanisms that ensure a continuous flow of natural capital development processes appropriate to the social and economic situation in the country.

To implement this concept, it is necessary to introduce innovations in the areas of environmental management, auditing, insurance, licensing, information and economics of natural resources, metrology, standardisation, certification, project management, etc. Specifically, it is necessary to organise: the development of legal standards (to create a legal basis and define a list

of activities, products, natural resource systems and territories subject to auditing and voluntary environmental certification, and the regulatory documents with which they must comply).

The mechanism for ensuring the ecological safety of territories (communities) is a systematic sequence of stages of scientific and practical research aimed at establishing reliable and justified criteria and identifying effective measures to improve the ecological state of natural resource systems.

The first block consists of determining quantitative indicators and criteria for ecological security, assessing adverse events, and determining the structure, system, and quantitative assessment of territorial security. The second block is designed for the evaluation of methods and mechanisms for ensuring territorial security, the implementation of this system into the practice of managing the socio-ecological-economic conditions of a given area, and the monitoring of the results of the implementation of the entire system.

The mechanism for implementing the concept includes individual phases, and the order of its implementation in Ukraine will depend on: the schedule for developing and approving the concept, the amendment of legislative and regulatory documents, their compliance at all levels of government and business, Ukraine's accession to the EU, as well as the formation of an ecological and state-centric worldview among all population groups and businesses.

The implementation of the KBAP will be carried out through the following approaches:

–The provisions of the concept must serve as a basis for the preparation of draft programme and strategic documents, draft laws and other legislative acts, as well as action plans in the socio-ecological-economic field.

–Measures to implement the paths to achieving the strategic goals and corresponding tasks of state economic policy must be included in the action plans of the Cabinet of Ministers of Ukraine and the relevant plans of the ministries.

–Existing strategic documents of the Cabinet of Ministers of Ukraine, action plans of ministries and other central executive bodies must be harmonised with this concept.

–The implementation of the concept is planned in three phases.

–In the first phase, the priority tasks should include: creating a legislative and regulatory framework; developing a strategy for implementing the KBAP; improving the integrated environmental management system, interdepartmental coordination and cooperation in the integration of environmental components into the development programmes of economic sectors; ensuring the development and approval of regional development strategies in relation to and in accordance with environmental management requirements; preparation of legal, budgetary, tax and financial-economic bases for the implementation of environmental audits and possible

voluntary certification; use of existing databases and monitoring of economic, environmental and social indicators at various levels.

The second phase is expected to include organisational, marketing and educational activities (special courses) to train experts in environmental management, auditing, insurance, certification and the provision of consulting services to organisations of all forms of ownership.

The third phase includes: the implementation of audit procedures (environmental audits) and their logical conclusion – the certification of buildings and community areas according to the initial tasks of innovation and investment development; the systematisation of all information and the creation of databases, including commercial ones.

Types of work to implement the concept:

1. Identification of adverse effects on natural resource management (NRM): The main objective of this phase is to identify a list of negative and adverse events that degrade the quality of NRM and directly or indirectly cause economic damage to the facility in question.

2. Assessment of facts and events: systematic assessment of adverse impacts that can be classified as risk or crisis events in a given period of time in a given area.

3. Determination of the structure of agricultural land use: this should ensure that land use is organised in a way that does not cause damage to NRM or harm public health. The basic principle is rational land use, according to which the level of anthropogenic impact must correspond to the ability of ecosystems to neutralise its effects.

This principle should be implemented through a system of territorial ecological standards for land use, calculated on the basis of ecological impact standards on NRM. The current system of ecological standards for maximum permissible emissions and discharges does not meet existing economic and social conditions. The assessment of the ecological status must be carried out by comparing the normative and actual levels of impact on NRM.

4. Quantitative safety assessment: includes studies aimed at developing quantitative indicators (integral assessments, expert opinions, models, real-time digital data, etc.) to be used in management decision-making.

5. Decisions on implementation and control in the field of agricultural land use safety management procedures: assessment of compliance (certification, including ecological) with the most optimal types of agricultural land use. Control of the results of individual stages of safety assessment is carried out during work related to NRM monitoring, auditing of existing facilities, licensing of activities, inspections by inspectors, etc.

The introduction of an effective audit and certification system (including organic certification) at various levels should be achieved through:

1. Administrative reform aimed at:

- the creation of a legislative and regulatory framework that takes into account existing international conventions, agreements and future trends in standardisation, certification and accreditation in the context of modern global competition;

- improving the list of products and services subject to mandatory or voluntary certification, including those that meet environmental standards, creating a register of environmentally certified products, facilities and areas of the NRM;

- developing methodologies that legally establish schemes, auditing and certification procedures and, accordingly, the accreditation of conformity assessment bodies;

- review and clarification of the functions, rights and obligations of central and regional state authorities and executive bodies in regulating integrated environmental protection activities at various territorial levels;

- reducing administrative interference in the production and economic activities of market economy entities by stimulating the implementation of safe use of agricultural land;

- theoretical and methodological harmonisation of the concept of certification as the final link in the system of state environmental and economic control, which includes preventive blocks (audits), study of the status of the certification object, licensing and voluntary certification blocks, environmental insurance, etc.;

- introduction of electronic services, elimination of corruption risks in the judicial system, improvement of the overall business environment, simplification of the registration system, obtaining permits and licences, simplification of tax administration.

2. Tax and financial reform:

- implementation of financial, credit and tax policies with the aim of creating an optimal tax system and benefits for businesses and administrative entities;

- reforming the mechanism for financing environmental protection measures in favour of businesses that implement environmentally safe business practices;

- establishing a system for financing local governments, manufacturing enterprises and organisations with the aim of stimulating the introduction of environmentally safe practices for the use of land as a whole (environmentally friendly business and tourism technologies, socially oriented enterprises, etc.);

- granting local (regional) authorities the right to accumulate funds for addressing environmental problems up to 60–90% from violators of environmental laws;

- introducing annual depreciation rates of 20% and 50% for equipment used for research and metrological support of auditing procedures and integrated NRM monitoring systems in the tax code;

- introduction of tax deductions of 30% of the profits from environmental savings realised from the profits of companies operating in certified areas;
- introduction of interest-free or low-interest loans for audits and certifications;
- differentiation of prices for raw materials and products produced in certified areas, starting with agricultural products (organic raw materials and products) and later services in the field of tourism, recreation, etc.

3. Transformation of investment activities:

- introduction of special regimes and investment activities in certified areas (including organic ones);
- stimulation of leasing and concession activities in certified areas to ensure the status and quality of NRM;
- creation of specially certified zones (territories) for investment in ecologically balanced projects (e.g. production of baby food, diet food and organic food).

4. Improvement of organisational and economic mechanisms for audit and certification systems:

- development of a methodology for ecological certification (including organic);
- monitoring existing and developing new legislative proposals, regulations and guidelines, including those relating to individual ministries;
- creation of a system of state guarantees and benefits through the creation of organisational and economic mechanisms for the implementation of certification of products, services, stable agricultural countries and territories in general;
- transformation of the mechanism for distributing payments between budgets at different levels;
- establishment of regional environmental insurance systems for the accumulation of funds and financing of auditing and certification procedures (including environmental ones);
- establishment of scientific, advisory and other bodies performing audits, certifications, etc.

The main objective of this reform should be to create a decentralised model of NRM management capable of effectively influencing socio-economic development processes in territorial areas in a market economy.

Creation of institutional conditions:

- creation of institutional infrastructure (a central certification body within the Ministry of Environmental Protection of Ukraine and independent environmental auditors with appropriate licences or certified commercial structures);

- professional training to obtain the relevant licence;
- expansion of the financial and economic opportunities of local communities and strengthening the motivation of local authorities to strengthen local budgets;

– public-private partnership tools, methodological approaches to the valuation of Ukraine's NRM (natural capital) assets, specifically:

5. Administrative and legal tools, such as legislative and regulatory frameworks (laws, resolutions of the Cabinet of Ministers, directives and opinions of international organisations) and standards (limits, quotas, etc.);

6. Economic instruments: subsidies, grants, loans, leasing, insurance, payments for the use of natural resources, pricing instruments and preferential taxation;

7. Communication and information support, education, public participation, multi-level monitoring of natural resource use, environmental engineering, consulting.

8. Financial support for implementation: Adequate financial resources should be allocated from the state budget of Ukraine for the implementation of the concept as a national document of significant importance. In addition, European and international aid funds may be mobilised. In order to reduce the time and costs of refining and implementing the concept and its regulatory support, a mechanism for cooperation between different ministries and agencies should be used.

9. Legislative and regulatory support includes:

- Amendments to Ukrainian laws «On Environmental Protection», the Law of Ukraine «On the Basic Principles (Strategy) of State Environmental Policy of Ukraine until 2030», «On Conformity Assessment», «On Standardisation», «On Metrology and Metrological Activity», «On Consumer Protection», «On Conformity Assessment», «On Waste» and others.

- Harmonisation of several EU directives regulating activities related to agricultural environmental management (KBAP), such as:

- a. Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment;

- b. Directive 2000/60/EC establishing a framework for EU water policy, as amended;

- c. Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe;

- d. Directive 2003/4/EC of the European Parliament and of the Council on public access to environmental information;

- e. Directive 2011/92/EU on environmental impact assessment (EIA), etc.

9. Development of legislative and regulatory documents, including a comprehensive legal framework for the certification of natural resource management (NRM) activities:

- development of technical regulations;
- maintaining mandatory certification of products and services during the period of economic reform in order to protect consumers from counterfeit products;
- introduction of voluntary certification in the field of natural resource management (including agriculture);
- continuing to harmonise Ukrainian legislative documents with international standards, etc.

10. Scientific and methodological support includes:

- legislative and regulatory documents of the Ministry of Environmental Protection, the Ministry of Economy of Ukraine, the EU, the WTO, and ISO;
- NRM quality methodology;
- the concept of total quality management (TQM) and the European Foundation for Quality Management (EFQM) model;
- certification schemes;
- strategies and concepts for the digitalisation and greening of the economy;
- scientific and methodological developments by the UN, FAO and experts;
- concepts in agribusiness and natural resource economics:
 - a. Inclusion of agricultural cluster development in the overall concept of cluster creation in Ukraine;
 - b. Creation of a regulatory framework for the functioning of agricultural clusters;
 - c. Creation of a system for monitoring land relations, deregulation of land administration, digitisation of licensing procedures and administrative services in the field of land relations;
 - d. Developing a national geospatial data infrastructure, transferring powers in the field of land regulation to local authorities;
 - e. Creation of legal, tax and financial-credit conditions for the active development of agricultural cooperation and other forms of associations of small producers;
 - f. Promotion of the «Industry 5.0» concept as a key factor in increasing the competitiveness of industrial enterprises in international markets;
 - g. Supporting educational activities aimed at transferring best practices from the IT sector to industrial sectors;
 - h. Creating new skills in the industrial workforce for the implementation of digital technologies;
 - i. Creating conditions for competition between local communities to attract investors;
 - j. Joining the European Smart Specialisation Platform (S3 platform).

The implementation of KBAP in the management of agricultural natural resources is possible through the organisation of innovation centres, which are best suited for:

- carrying out audit procedures and later certification procedures;
- Supporting existing and creating new innovative businesses;
- providing information and analytical support for programmes and projects;
- facilitating the creation of joint ventures;
- providing consulting and engineering services;
- Involving small businesses in the innovation sector, etc.

Scientific rationale The implementation emphasises the importance of transitioning to more sustainable natural resource management systems in government, business, community life and food systems based on green economy practices:

- First level: The primary focus here is on improving resource efficiency by applying methods that reduce or completely eliminate the use of expensive, non-renewable, rare or environmentally harmful production resources.

- Second level: This involves using alternatives to chemical production resources to incorporate ecological processes more extensively through methods such as symbiosis with biota (plant microbiome or natural enemies) or genetic traits (e.g. resistance to biotic stress) to improve nutrient uptake, stress tolerance and protection against pests and diseases.

- Third level: This level involves modernising agricultural systems to make them more resilient to external factors, including through diversification, resource recycling, rational land use, self-sufficiency and reduced dependence on production resources. Examples include increasing the diversification of agricultural structures and their management through crop rotation, polyculture, agroforestry and the introduction (or restoration) of integrated livestock and crop farming.

- Fourth level: This involves restoring links between producers and consumers through alternative food distribution networks such as farmers' markets, responsible food trade principles, and the promotion of social equality and environmental responsibility.

- Fifth level: This level involves creating new local and regional food systems based on the secure management of agricultural natural resources.

Implementing this concept requires the use of digital technologies.

Digital technologies contribute to the balanced management of agricultural resources and, in particular, to the creation of sustainable food and agricultural systems. These include, in particular, precision farming technologies, big data, automation and alternative web platforms. For example, precision farming technologies include equipping agricultural machinery with sensors

which, using appropriate software platforms, ensure the archiving of data at farm level (on crop cultivation, yields, soil, climate) and provide weather forecasts. With the help of other resources (platforms, electronic calculators, etc.), farmers receive recommendations on their mobile devices about which crops to grow, which varieties to use, where and when to sow, and when to harvest. Advances in remote sensing technologies, including the use of satellites and drones, have enabled real-time data exchange, supporting real-time decision-making. These tools are increasingly being used in various aspects of agricultural resource management and in other areas of knowledge and business.

The expected outcome of implementing this concept is to establish and publicly support the strategic direction of the state in the socio-ecological-economic sphere. Its gradual implementation will enable:

- the creation of competitive conditions for agribusiness and investment in high-quality (adequate) natural resource management (NRM);
- an increase in GDP per capita;
- increase labour productivity;
- an increase in export volumes;
- maintaining the quality of NRM.

The results of implementing the KBAP and, consequently, food security can be achieved by complying with FAO provisions relating to the four dimensions of food security (availability, access, utilisation and stability) and the three main factors of security (access to food, care and nutrition, health and hygiene), which are currently generally recognised by the FAO [50].

The positive results of KBAP implementation are formulated as follows:

1. Availability of sufficient quantities of food of adequate quality supplied through domestic production.
2. Ensuring a complete diet, clean water and hygiene measures to achieve food security that meets all physiological needs.
3. Stability: To ensure socio-ecological-economic development, the state and individuals must have access to high-quality NRM and the ability to properly use the environment, human resources, production factors, processes, infrastructure and institutions, as well as activities related to the production, processing, distribution, handling and consumption of food and the results of these activities.

The expected results of implementing KBAP as a new ideology in the field of agricultural resource management and environmental protection in Ukraine will be reflected in:

- creating an effective environmental management system in administrative entities and in individual private and state territories, creating an information space for the protection and rational use of natural resources, reducing environmental threats and risks;
- mixed (state and private) auditing and certification procedures (through third-party certification schemes);
- significant increase in investment attractiveness thanks to transparency of information on the state of natural resource potential;
- increase in revenue at all levels of government thanks to growth in production, investment and transparent financial policy rules;
- an increase in the number and commercial activity of companies focused on environmental protection;
- modernisation of the legislative and regulatory framework and infrastructure in the field of standardisation, metrology, conformity assessment and consumer protection, aimed at the innovative development of Ukraine and its integration into the global community;
- significant progress in raising environmental awareness among consumers;
- attracting investment, reducing capital investment risks and creating additional opportunities to increase the competitiveness of products manufactured in certified territories and communities within various enterprises;
- ensuring product safety for NRM, the life, health and property of Ukrainian citizens, etc.

The anticipated developments in the field of agricultural resource management require the implementation of Ukraine's provisions on European integration, environmental management, auditing and subsequent environmental certification in the natural resource management sector as the final stage of conformity assessment after fulfilling a set of economic, environmental and social tasks. For example, harmonisation of the 'Guidelines on the interpretation and application of Directive 2005/29/EC of the European Parliament and of the Council concerning unfair business-to-consumer commercial practices in the internal market'. Its aim is to raise awareness of the Directive among all stakeholders, such as consumers, businesses, Member State authorities, including national courts and legal practitioners, throughout the EU. It includes amendments made by Directive 2019/2161 of the European Parliament and of the Council on better enforcement and modernisation of Union consumer protection rules, which entered into force on 28 May 2022.

In order to ensure that regional interests prevail over the interests of individual companies and organisations, it is necessary to consolidate socio-economic guidelines with appropriate organisational and economic management levers:

- incentive and information levers (for example, environmentally certified resource users and specific territories receive more funding because they are significantly less risky);
- organisational levers (organising audits and certification of raw materials, products, services and territories in accordance with the requirements of the Ukrainian Ministry of Economy);
- restrictive instruments (e.g. a ban on the sale of non-certified baby food products);
- preventive tools (e.g. certification of agricultural land and forests to guarantee the supply of high-quality raw materials, which is already being implemented in Ukraine);
- penal measures (a system of fines for non-compliance with mandatory certification requirements or falsification of product quality), etc.
- tax reform in Ukraine stimulates auditing and certification procedures for products, services and natural resource management and will deliver the expected results under the following conditions:
 - ensuring macroeconomic, social and political stability in society;
 - combination of state and market economic mechanisms to stabilise, rationally use and preserve the quality of natural capital;
 - availability of non-fiscal conditions, in addition to fiscal ones, for activating investment processes – reliable protection of property rights, genuine harmonisation of fiscal and monetary policies;
 - ensuring the independence of the judiciary and executive, competition and contracts;
 - ensuring transparency in economic relations, for example by introducing a 5% purchase tax;
 - reducing the level of corruption, a conscious approach and protection of public interests;
 - effective use of state funds obtained from taxes and fees, rationalisation of the structure of state expenditure towards increased state investment in human and natural capital.

The economic instruments of ecological and economic regulatory mechanisms in Ukraine and the appropriateness of their use, the instruments of state environmental policy, and the main factors influencing the development and implementation of ecological certification are described in detail in [42-44].

In order to transform food systems based on fundamental changes in the methods and content of production, processing, transport and consumption, a number of measures need to be taken to transition specific production methods and all stages of the food production and distribution chain. Based on active interaction between innovations in food businesses, information and education activities of public movements and policies (Spaargaren et al., 2011;

Hinrichs, 2014), [51, 52], it is possible to gradually create more sustainable models of production and consumption.

The concept implements the provisions of multilateral partnership mechanisms in the area of financing and strengthening food security and improving nutrition as part of the implementation of the Agenda for the period until 2030 [53], for example, the Association Agreement between Ukraine and the EU [54-57].

Insurance risks. Agricultural insurance is one of the riskiest segments of the agricultural market. This is because insurance companies are often forced to compensate for damage caused by extreme weather conditions, crop damage, etc. Ensuring solvency, as well as improving the effectiveness of risk analysis and decision-making on the feasibility of certain types of activities, is achieved through insurance of the activities of a specific applicant.

CHAPTER 3. JUSTIFICATION FOR THE INTEGRATED USE OF LAND AND WATER RESOURCES TO ENSURE ECOLOGICAL AND ECONOMIC SECURITY

Human use of water and land for agricultural purposes has not yet peaked, but all available evidence points to a slowdown in agricultural productivity growth, a rapid decline in production capacity and increasing environmental damage. The expansion of environmentally responsible and climate-smart production can reverse current trends in soil and water degradation and promote inclusive growth. This approach is consistent with the objectives of the FAO's strategic framework [58]: «better production, better nutrition, a better environment and a better life».

Over the past decade, several important global policy frameworks have emerged, including the 2030 Agenda for Sustainable Development, the Paris Agreement on Climate Change, the Sendai Framework for Disaster Risk Reduction 2015-2030 and the New Urban Agenda. Within these frameworks, countries are implementing the Sustainable Development Goals (SDGs), their Nationally Determined Contributions (NDCs) and the concept of Land Degradation Neutrality (LDN). Specifically, the Sustainable Development Goals address water resources as well as goals related to soil protection and soil health. The implementation of these global mechanisms is accompanied by a comprehensive assessment of natural resources – including soil, forests and biodiversity – along with analyses of desertification and climate change.

The unpredictability of climate change and the complex interconnections between climate systems and the planet increase the risks facing agriculture. This challenge requires urgent action. Global assessments point to a convergence of factors that have created unprecedented pressure on soil and water resources, affecting people's livelihoods and disrupting agricultural supply chains, particularly in the food sector.

Land and water management are among the priority areas that require transformation. Long-term management of land, water and, in particular, soil health is essential to ensure access to food in a situation of growing demands on the food supply chain, to guarantee environmental safety in production, to promote fairness in access to livelihoods and to strengthen resilience to shocks and stresses associated with natural disasters and pandemics. At the heart of these challenges are issues of access to and management of land and water resources. Sustainable land, soil and water management also contributes to ensuring a diverse and nutritious diet and to building resource-efficient production and supply chains as part of the transition to sustainable consumption patterns.

In times of severe shocks – such as floods, droughts, the COVID-19 pandemic and armed conflicts – development priorities often take a back seat. As a result, the gap between developed and developing countries in achieving global development goals widens, particularly in the context of new waves of infection and rising mortality. However, recovery programmes provide

opportunities to address urgent needs and initiate transformative changes, including in the management of land and water resources. Land and water resources – and how they are used – are key to achieving global food security. Ensuring the long-term and sustainable management of these resources is crucial to securing access to food amid growing pressure on the food chain, maintaining environmental safety in production, promoting equitable livelihoods, and increasing resilience to shocks and stresses caused by natural disasters. Demographic challenges, climate change and growing competition for land and water in conditions of food insecurity are likely to further increase the vulnerability of populations.

The world's population continues to grow. By 2050, the current population of 7 billion is expected to reach approximately 9 billion. By then, an additional 1 billion tonnes of cereals and 200 million tonnes of animal products will need to be produced annually. The challenge of increasing agricultural production is particularly acute for developing countries, where the problem lies not only in food production but also in ensuring that households have access to food in order to guarantee food security.

Water and soil resources play a key role in the functioning of natural systems (the weighting factor reflecting the relative role of the *i*-th component in the functioning of the natural system is 1 for soil and 0.95 for water resources [59]). The ecological stability of natural systems and ecological-economic security depend on how efficiently water and soil resources are used in various sectors of the national economy, including agriculture. However, research shows that natural resources – especially in irrigated agriculture – are used inefficiently.

In 2020, 9.6 km³ of fresh water was withdrawn from natural water sources (90% from surface sources and 10% from groundwater sources). Over the last decade, Ukraine has seen a 1.5-fold decrease in water consumption (from 14.8 km³ in 2010 to 9.6 km³ in 2019) and a decrease in wastewater discharge (from 7.8 km³ in 2010 to 5.2 km³ in 2020). These trends are attributed to a decline in industrial and agricultural production, reduced water consumption due to rising water tariffs, and a slight decrease in water losses. Agriculture accounts for approximately 29% of total water consumption. The structure of water consumption in agriculture is as follows: production needs – 60%; irrigation – 21.4%; drinking water and hygiene needs – 17.3% [60].

Findings indicate that water waste and diffuse water pollution are serious problems in Ukraine's agricultural sector. One of the main factors contributing to diffuse pollution and depletion of water resources is improper agricultural practices. Failure to comply with environmental requirements – such as excessive use of mineral and organic fertilisers and pesticides, improper storage of agrochemicals, and the spread of intensive livestock farming without adequate modern infrastructure for the safe management of manure and waste – leads to the contamination of groundwater hydraulically connected to surface water. The situation is

exacerbated by the extensive use of agricultural land, ecologically unjustified land improvement in some regions and violations of environmental protection standards in agricultural activities. Analysis shows that developed countries consume four times less water than developing countries to produce 1 tonne of grain, while Ukraine needs four times more water per tonne of grain than developed countries. Compared to Finland, Poland and Germany (which have a similar share of agriculture in the national water consumption structure), water consumption intensity per GDP in Ukraine is approximately nine times higher, and water consumption intensity in agriculture is 3-6 times higher [61].

Water losses during transport from water sources to consumers are also significant. According to operational data from water management authorities, unplanned water leakage from large inter-farm systems accounts for 30% of total water abstraction, while the water consumption coefficient in the field is only 60-70% of the water supplied. Depending on the type of crop, annual humidity and region of cultivation, water consumption standards in agriculture are overestimated by 24.7%.

Similar trends are also observed in the use of soil resources in agriculture. In recent years, there has been a steady decline in productive agricultural land, especially arable land, due to a lack of financial and technical capacity to maintain it in good condition. As agricultural producers do not have sufficient financial resources, measures aimed at preserving and improving soil fertility are not being implemented. Agrotechnical, agrochemical, ameliorative, phytosanitary and anti-erosion practices are neglected and long-term land abandonment is allowed, leading to soil degradation – overgrowth with shrubs and a decline in productivity.

Almost all economic entities in Ukraine continue to show a trend of soil degradation. In most cases, soil cover, especially agricultural land, is highly susceptible to degradation and contamination and is rapidly losing its resistance to destruction, its ability to restore its properties and its ability to regenerate fertility. This is largely due to exploitative land use practices, the inability of public authorities to adequately assess soil conditions, and the lack of scientifically based comprehensive measures for its rational use. Dangerous degradation processes that are intensively developing throughout Ukraine include erosion, deflation, waterlogging, salinisation, desertification, flooding and the overgrowth of agricultural land with shrubs. These processes ultimately lead to a loss of soil fertility and the removal of land from agricultural use.

The reduction in the total area of agricultural land – including irrigated and drained land – and the deterioration in the recultivation and economic use of this land, combined with heavy metal contamination, are reducing the stability and security of natural systems.

It is also important to note that existing agricultural practices primarily benefit farmers who own fertile land and have reliable access to water, unlike most small producers. These producers

continue to struggle to achieve high yields, suffer repeated financial losses and remain vulnerable to soil degradation and climate anomalies.

The institutions responsible for managing soil and water resources are unable to keep pace with the growing intensity of economic exploitation of river basins, the increasing interdependence between soil and water resources, and the growing competition for their use. Therefore, more adaptable and flexible mechanisms are needed to effectively address the scarcity of natural resources and preserve economic and market potential.

According to FAO projections [58], population and income growth will require a 70% increase in global food production and a 100% increase in developing countries by 2050 compared to 2009 levels. However, the distribution of land and water resources is unfavourable for countries that need to expand production: in low-income countries, the availability of arable land per capita is on average more than twice as low as in high-income countries, and the suitability of arable land for crop cultivation is generally lower. Some countries with rapidly growing food demand also face acute shortages of land and water resources. It is therefore likely that future increases in agricultural production will be achieved mainly through the intensification of existing agricultural land. This requires the widespread introduction of sustainable land management practices and more efficient use of irrigation water through increased flexibility, reliability and timeliness of irrigation water supply.

Many soil and water systems are currently threatened by a gradual decline in their production potential due to excessive demographic pressure and unsustainable agricultural practices. Within these systems, physical constraints on the availability of soil and water resources may in some cases be exacerbated by external factors such as climate change, competition with other sectors and socio-economic transformations.

One of the key challenges facing agriculture is to combat soil degradation and reduce emissions, while preventing further environmental pollution and loss of ecosystem services without compromising production levels. Addressing this challenge requires climate-smart use of soil resources, organised with regard to the variability of processes occurring in soils and water. If innovations in management and technologies that enable the transition to sustainable agri-food systems can be scaled up, various agricultural practices can be used to increase productivity and production levels. However, without proper planning and integrated (joint) use of soil and water resources, achieved through effective management of these resources, such progress is not possible.

Mo Lee, Qiang Fu and Vijay P. Singh [62] emphasise the need to balance and harmonise economic, environmental and social considerations in irrigated agriculture, optimally and simultaneously allocate limited agricultural water and soil resources, and address the complexity

of non-linearity and fuzzy uncertainty that arise in such allocation processes. Using the multi-objective fuzzy-reliable programming (MOFRP) method to support the optimal use of soil and water resources in agriculture, it has been demonstrated that jointly considering the costs of water and soil resource maintenance together with ecosystem services during crop cultivation can increase the economic and environmental benefits for agricultural enterprises by up to 18.8% [63]. Therefore, integrated management of water resources and agricultural land is currently the most important and effective approach to mitigating increasing water scarcity and preventing environmental degradation [64].

In our opinion, the application of integrated approaches to soil and water resource management is therefore of critical importance.

Ultimately, sustainable land management and integrated water resource management must be combined with technological innovations aimed at rapidly improving resource efficiency.

There are now a number of proven and cost-effective soil management practices that reduce waste and ensure more efficient water use in agriculture, bringing additional benefits to natural production systems and increasing long-term agricultural productivity. These include improving water availability and efficiency (infrastructure modernisation, eco-friendly farming, collective irrigation management, rainwater harvesting, grey water and wastewater reuse, etc.); reducing water demand (crop selection, climate-adapted agriculture); and supporting landowners (insurance against adverse weather conditions). However, these practices are not widely applied. This is due to factors such as a lack of labour or investment, as well as the presence of disincentives – such as subsidies and legal norms – that do not promote efficient use of resources [65].

Although attempts to introduce integrated water resource management have been made for decades, their practical success is often limited due to sectoral interests, political and administrative barriers, and the inability to foster a sense of collective responsibility. Water resource managers have traditionally worked in isolation, with efficiency largely dependent on sustainable land management [66].

One example is the seven-year integrated water resources management project in the Hai River basin in China, which initiated reforms in water and soil resource management aimed at improving the quality of river and groundwater resources and reducing water consumption for irrigation. The project clearly demonstrated several key elements of the national programme for the protection and rational use of water resources, including: a central institution supported by comprehensive water management legislation; coordinated land and water use planning at regional and river basin management authority level; decision-making standards based on long-term water supply and demand; relevant services in the field of research, demonstration projects and knowledge dissemination; a demand management system; quality control of equipment; support

for water user associations; and, where necessary, land reform and agricultural loans for investment in irrigation [67].

No reform is possible without the participation of farmers, who are key players in this process and whose perspectives must be taken into account. Farmers must be involved in the planning and sustainable management of water and soil resources, but many of them are forced to rely on unsustainable agricultural practices due to poverty and lack of incentives, uncertain land and water ownership, the absence of functioning local soil conservation organisations and ineffective support services, including credit and finance for rural areas, markets and access to technology and knowledge. In this case, the allocation of public resources can be more strategic when combined with mechanisms to mobilise private sector financing at both national and local levels. This should lead to an increase in the share of public investment in agriculture.

The involvement of all stakeholders at all levels of water and land resource management can significantly improve water productivity and reduce pressure on water resources by increasing the efficiency of water allocation between sectors and adopting technologies and management structures that promote efficient water use. Examples include collective irrigation systems or joint groundwater management. Cooperation in transboundary water resource management – starting at the technical level – can facilitate optimal multi-purpose investments and benefit sharing in river basins.

Current approaches to river basin management reflect best practices in decentralising water and land management to the lowest appropriate regional level and ensuring stakeholder participation in planning and decision-making. When addressing issues related to the level and methods of intensification, protection and conservation, balancing commercial agriculture with staple crop production, as well as reconciling income growth with distribution, ensuring national food security and sharing costs and benefits between urban and rural populations, it will be necessary to take into account both positive and negative factors.

Effective cooperation between the institutions responsible for water and soil resources does not correspond to the actual structure of their use and consumption. Although water and soil function as an interconnected system, they are managed separately. While in the legal sphere the division of water and soil resources is intended to prevent their misuse or illegal appropriation, the increasing intensity of river basin development, the growing interdependence between water and soil resources, and the growing competition for them create a need for more integrated and flexible management bodies capable of addressing the scarcity of natural resources and responding to changing market conditions.

Even institutions whose main mission is the comprehensive management of a region or river basin tend to focus primarily on water resources or soil resources alone, as well as their respective multipurpose uses, rather than managing water and soil resources together.

In our view, effective joint use of water and soil resources requires planning to be one of the most important components of the decision-making process (Fig. 3.1).

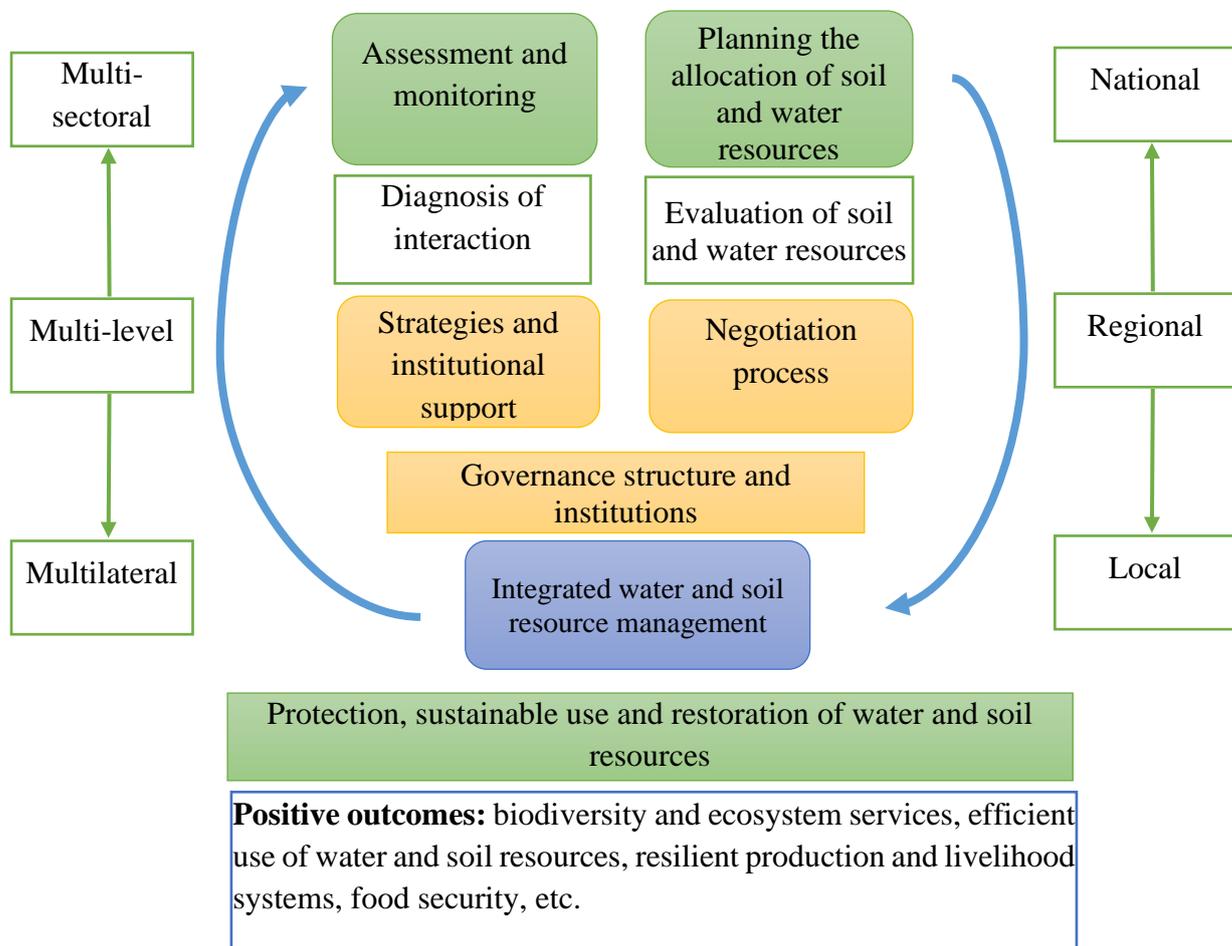


Fig. 3.1. Planning as part of the decision-making process in integrated water and soil resource management (prepared by the author)

It involves a systematic assessment of the potential of soil and water resources, as well as an analysis of alternatives for their optimal use and improvement of economic and social conditions based on a participatory process involving all stakeholders.

Planning is one of the most important components of integrated management. It involves assessing water and soil resources, identifying needs and objectives for their use, selecting and implementing optimal sustainable resource management technology options at various levels (for individual enterprises, regions or at the national level), as well as monitoring and evaluating results in order to inform decision-makers and other stakeholders.

It should be noted that the coordination process during resource planning is multi-stage. Resource planning through a stakeholder negotiation process is illustrated in Fig. 3.2.

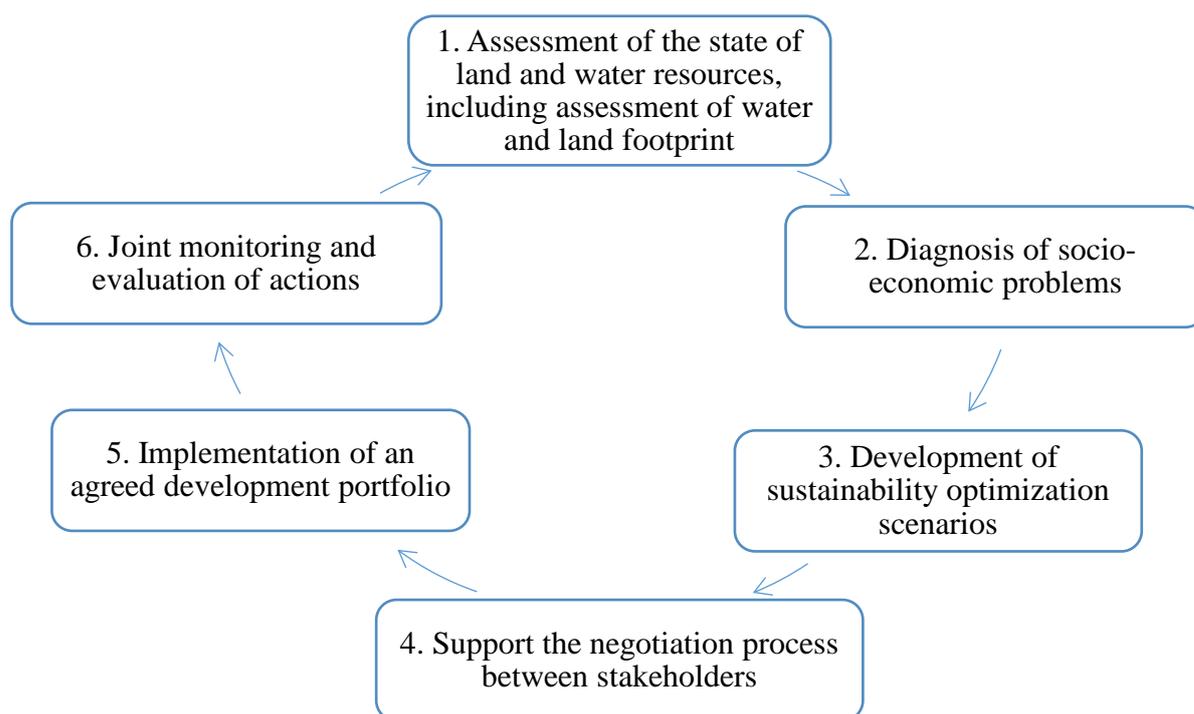


Fig. 3.2. Resource use planning through a stakeholder negotiation process (developed by the author based on [63])

Joint management of water and soil resources is a process that depends on the extent to which different stakeholders and sectors are involved. Stakeholder participation should therefore be at the heart of this process, while governance, policies and institutions serve as means for planning the use of water and soil resources. Political and institutional support is necessary at all levels to ensure coherence between national and sub-national economic, social and environmental objectives and the needs of stakeholders (both public and private) and to achieve a balance between their interests.

Therefore, in order to establish effective joint management of water and soil resources, it is necessary to set up a permanent commission under the Ministry of Agricultural Policy and Food of Ukraine. Such a commission would empower river basin councils, together with local communities, to take decisions on water and soil resource management tools and mechanisms in their territory, together with landowners. It would also enable the redistribution of functions and responsibilities and the establishment of principles and rules of conduct (Fig. 3.3).

Experience with integrated river basin management aimed at improving soil resource management is demonstrated by the Kagera River Basin Transboundary Agroecosystem Management Programme, one of 36 projects under the TerrAfrica Strategic Investment

Programme, which aims to strengthen soil resource management in sub-Saharan Africa. The Kagera River Basin (Burundi, United Republic of Tanzania, Rwanda and Uganda) supports agriculture, pastoralism and fisheries for more than 16 million people. However, rapid population growth, agricultural intensification, progressive farm size reduction and poor land and water management practices have led to resource degradation.



----- structures proposed for establishment and development

Fig. 3.3. Institutional support for joint management of water and soil resources (prepared by the author)

To promote joint sustainable management of land, water and biodiversity resources, approaches to river basin planning and management have been incorporated into local government strategies. In Burundi and the United Republic of Tanzania, river basin management groups have been established to set priorities and monitor river basins. Such joint land use planning has enabled communities and governments to adopt river basin management and integrated agricultural ecosystem management plans aimed at improving agricultural productivity and addressing challenges related to natural resources, climate, biodiversity, food security and livelihoods [68].

The Permanent Commission for Joint Management of Water and Soil Resources is an institutional body under the Ministry of Agricultural Policy and Food of Ukraine. Its functions will include: collecting information on the use of water and soil resources; assessing the state of water

and soil resources, including assessing the water and soil footprint; drafting and approving contracts for the lease of land together with water bodies located on that land; monitoring changes in the water and soil footprint in a given territory; and making decisions on the application of economic and/or administrative instruments in cases of positive or negative dynamics of water and soil footprint indicators in order to regulate the activities of enterprises that use soil resources and water management facilities, etc.

It should be noted that the effect of implementing control measures in water management organisations is determined as a cumulative result u , which prevents crop losses through operational regulation of the water regime, prevents excessive drying of agricultural land, reduces the need for irrigation and generally increases the resilience of the regional ecological and economic system. The economic effect of implementing an agricultural production management system takes into account the benefits of improving soil quality, saving financial resources, preventing crop failure and the potential for outsourcing in agricultural management.

The maturity and effectiveness of joint interaction between water management organisations and agricultural enterprises thus largely depends on the level of funding and information support provided by the territorial bodies of the State Water Management Agency and regional agricultural development departments. The efficiency of agricultural enterprises is determined by their compliance with market needs and the extent to which water management organisations meet the requirements for the operation of reclamation systems for agricultural production on drained agricultural land.

The organisational toolkit for joint management [69] of the activities of water management organisations and agricultural enterprises (Table 3.1) contains a set of tools and models that enable the improvement and increase of the efficiency of their activities.

The effectiveness of the joint management system between water management organisations and agricultural enterprises therefore depends on their level of institutional maturity and is determined by the extent to which they are capable of self-realisation and continuous improvement.

Currently, the effectiveness of such cooperation is reflected (and produces systemic results) in national programmes aimed at addressing specific economic and environmental challenges through government resolutions and can be successfully implemented in the form of public-private partnerships.

Table 3.1

Organisational tools for the joint management of water management organisations and agricultural enterprises (developed by the author)

Basic tools for managing the activities of water management organisations	Basic tools for managing the activities of agricultural enterprises
<ul style="list-style-type: none"> • Risk management • Management accounting • Good governance approach (includes principles of efficiency and effectiveness, assuming that processes and institutions deliver results that meet the needs of society while making the best use of available resources). For standard processes – use of reference models, in particular for: selecting and modelling the main sequence of work procedures; determining key performance indicators (KPIs) and parameters that enable the effectiveness of activities to be assessed and the causes of problems to be identified. • Rapid assessment model for evaluating irrigation water supply indicators based on agricultural soil moisture • Information on environmental and reclamation monitoring 	<ul style="list-style-type: none"> • Control • Budgeting • Reference models for analysing the condition and trends of agricultural land • Environmental audit of the condition and trends of crop yields (certification within the environmental management system of the entire territory where water and soil resources are used as one of the main sources of income) • Information on ecological and agrochemical monitoring • Rapid assessment of production process management • Investments in innovation and market needs (biomass cultivation, organic products, etc.) • Assessment of water and soil footprint
<p>Reference models, environmental and remediation audits, outsourcing, benchmarking and reengineering of innovative and successful companies in the sector System of corrective measures for project and programme management and early warning mechanisms for risks (SWAP model)</p>	

An appropriate organisational and economic mechanism is needed to implement joint water and soil resource management. It should include the key components of such management and focus on the application of management approaches, ensuring the appropriate use of soil and water resources, and jointly financing the renewal of the material and technical base of agricultural enterprises and water management organisations on new, innovative foundations. This will enable the socio-ecological and economic functioning of enterprises, ensure efficient and uninterrupted agricultural production and, as a result, maintain an adequate level of food security.

By mechanism, we mean a set of interacting organisational and economic components. In this context, the organisational component of the mechanism includes structures that organise the process and system of relationships, as well as forms, methods and regulations of control influence on changes in the state (or development) of the system. The economic components of the mechanism include a set of principles and rules for implementing relationships, as well as methods and means of achieving the system's objectives – i.e. the tools through which relationships are implemented and the process is carried out.

On this basis, in our opinion, the organisational and economic mechanism of joint water and soil resource management should be understood as a set of institutions, principles, rules, approaches and measures aimed at organising effective agricultural and water management production and expanding their production and financial capacities (Fig. 3.4).

The proposed mechanism includes the following components in particular:

1. Organisational components: creation and development of a specialised institute for the joint management of water and soil resources; business companies; cluster associations at regional level.

2. Economic components: development of market relations in agriculture and water management; pricing of agricultural products; water tariff policy; land rental costs, etc.; legislative and regulatory framework, including scientific, legal, personnel, technical and information support (socio-ecological-economic monitoring), forming the basis for the implementation of the water and soil resource management process.

The main management entities may include the Commission for Joint Water and Soil Resource Management, the State Water Agency, farmers, clusters, risk companies and others.

The process of joint management of water and soil resources includes the implementation of joint complex projects, as well as the introduction of economic incentives and sanctions in the event of positive or negative dynamics of water and soil resource use indicators. It also includes planning the use of water and soil resources through a process of stakeholder negotiations, assessing the extent and monitoring the dynamics of changes in the water and soil footprint, forecasting the feasibility and efficiency of land and water use, and implementing organisational and legal management measures.

The management process is carried out through administrative, economic and social methods and tools, leading to the achievement of security through the economically efficient, socially necessary and environmentally balanced operation of water management and agricultural enterprises.

As is well known, the water sector requires significant capital investment, which increases current costs but can have long-term effects by reducing losses in the national economy as a whole. Investments in water infrastructure with a long payback period can therefore stimulate economic growth in other sectors of the economy through external multiplier effects.

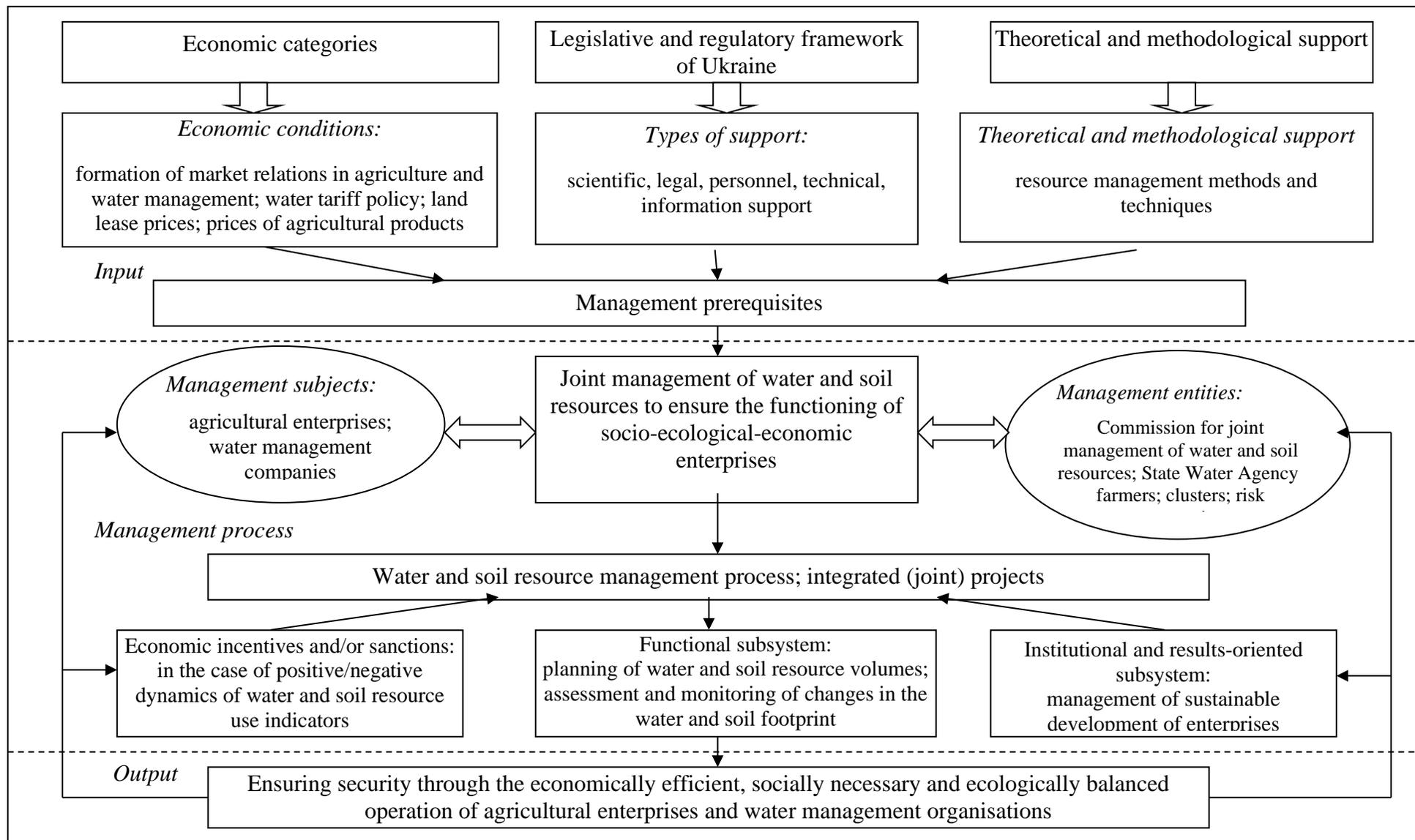


Fig. 3.4. Organisational and economic mechanism for implementing joint water and soil resource management (prepared by the author)

When assessing the efficiency of water management infrastructure, attention should be paid not only to the economic indicators of companies in the water management sector (profit, profitability, liquidity, return on fixed assets, working capital turnover, labour productivity, etc.), but also to the extent of the impact of water management organisations on agricultural production, namely:

- timeliness and completeness of meeting the demand for water for agricultural production;
- efficiency of irrigation infrastructure use;
- amount of unproductive water losses (an increase in this indicator leads either to higher costs for water management organisations, which are not covered by consumers, or to additional payments for water by agricultural producers);
- reduction of costs in the water supply process.

The additional effect for the agricultural sector resulting from the joint use of water and soil resources together with the water management sector can be expressed as additional profit generated by an increase in production volume and improvement in product quality through the use of innovative production technologies compared to the output that an agricultural producer would achieve under similar conditions but without the use of such technologies. Since the revenues of water supply companies are generated at the expense of part of the revenues of agricultural producers, it is necessary to take into account the economic priorities and technical factors of production and service provision in order to increase the efficiency of companies in the water management sector and agricultural enterprises.

Given the insufficient budgetary resources for land restoration, water management activities and the significant deterioration of water management facilities and infrastructure, it is necessary to involve the non-state sector in the management of soil resources and water management activities, in particular in the provision of water supply services and the repair and maintenance of water management systems.

New forms of public-private partnerships will play an important role in shaping such a market in the water management sector.

Currently, most agricultural enterprises (especially agroholdings) intensively use leased agricultural land to achieve maximum short-term income, regardless of soil depletion and degradation. The main reason for this is the absence of the tenant's right to manage infrastructure facilities in the area. This means that if a land user leased land on the basis of a public-private partnership, such as a concession, then when taking over water management infrastructure facilities into operation, they would have a legitimate interest in their

development. One of the mandatory conditions for leasing land on the basis of a concession is compliance with land use requirements, in particular keeping the land in good condition.

The indicators for assessing the level of water and land resource use will be the water footprint and land footprint, as well as the dynamics of their changes over the years. Tenants who maintain these indicators within the normative range will be eligible for various incentives, while those who fail to meet the requirements and overexploit the land will be subject to sanctions (Table 3.2).

Table 3.2

Proposals for economic incentives and sanctions in the case of positive/negative dynamics of water and soil resource use indicators

No	Name	Proposal	Note
<i>Economic measures</i>			
1	Corporate income tax	50% reduction	Provided there is a positive trend in water and land footprint indicators
2	VAT	Reduction to 0	The VAT amount credited to agricultural holdings is not payable to the budget and remains fully available to the agricultural holding.
3	Flat-rate agricultural tax	Reduction of 25	In the event of positive dynamics (3-5%) in reducing the water and land footprint.
4	Tax holidays	Extension by 6 months	In the case of positive dynamics of water and land footprint indicators
5	Full or partial interest-free loans	Up to 50	Provided that: inflation indexation applies; irrigation and soil infrastructure on leased land is modernised
6	Accelerated depreciation of fixed assets	-	Provided that irrigation and land infrastructure on leased land is modernised. May include depreciation of buildings with an original zero book value
<i>Administrative measures</i>			
7	Penalty	Up to 150 non-taxable minimum incomes for citizens	For emissions of harmful substances into the air
8	Fine	Up to 100 minimum incomes of citizens, which are not taxable	In the case of negative dynamics of water and land footprint indicators
9	Penalty	Up to 250 times the minimum income of citizens, which is not taxable	For excessive use of agricultural land (based on land footprint)
10	Penalty	Up to 250 times the minimum non-taxable income of citizens	For excessive use of water resources (based on the size of the water footprint)

In our opinion, one of the most suitable forms of cooperation for the effective joint management of water and soil resources is the cluster approach.

For agricultural enterprises that will be part of the cluster, the main production factor is agricultural production: grain and other crops, vegetables, milk and meat. Water resource management organisations will act as service providers – suppliers of the most important raw material, water. The relationship between agricultural producers and suppliers of resources (material, labour, financial) and services is key to the development of these sectors and is highly interconnected in real-life conditions.

Agricultural producers cooperate with both direct and indirect suppliers.

Direct suppliers include providers of equipment necessary for the production process, electricity, fuel, water and human resources, as well as research institutions.

Indirect suppliers include those who provide financial, construction, transport and storage services. It should be noted that the degree of development of these interactions varies. This means that some components of the cluster are still underdeveloped and do not fully meet the needs of other cluster participants. Exporters, wholesalers, retailers and distributors with whom agricultural producers cooperate will also be participants in this cluster, and these interactions are characterised by strong interdependence.

A high level of infrastructure support is necessary to ensure the effective functioning of the cluster (Fig. 3.5). Particular attention should be paid to the development and proper maintenance of infrastructure for agricultural water management. Increasing the efficiency of water management organisations that supply irrigation water will reduce the costs of rural producers' end products.

The main task of an effective system of interaction between water management organisations and agricultural enterprises is to ensure the possibility of supplying the necessary amount of water at the right time through the organised use of technological and other resources for the provision and payment of water management services.

When creating clusters, the concept of synergy is applied, i.e. a set of advantages that arise when several entities join together in a single group structure. These advantages are based on internal connectivity and interaction, i.e. on the effect of mutual reinforcement. The effective functioning of all components included in the cluster structure can be organised on the basis of joint management.

It is therefore necessary to establish a high level of production and economic relations between agriculture as a producer of end products and the water sector as one of the key suppliers of resources and thus a participant in the agricultural production system. Such an

integrated system will enable each link in the chain to maximise the satisfaction of its needs through the most efficient use of internal resources, which will be achieved by bringing together businesses from different sectors.

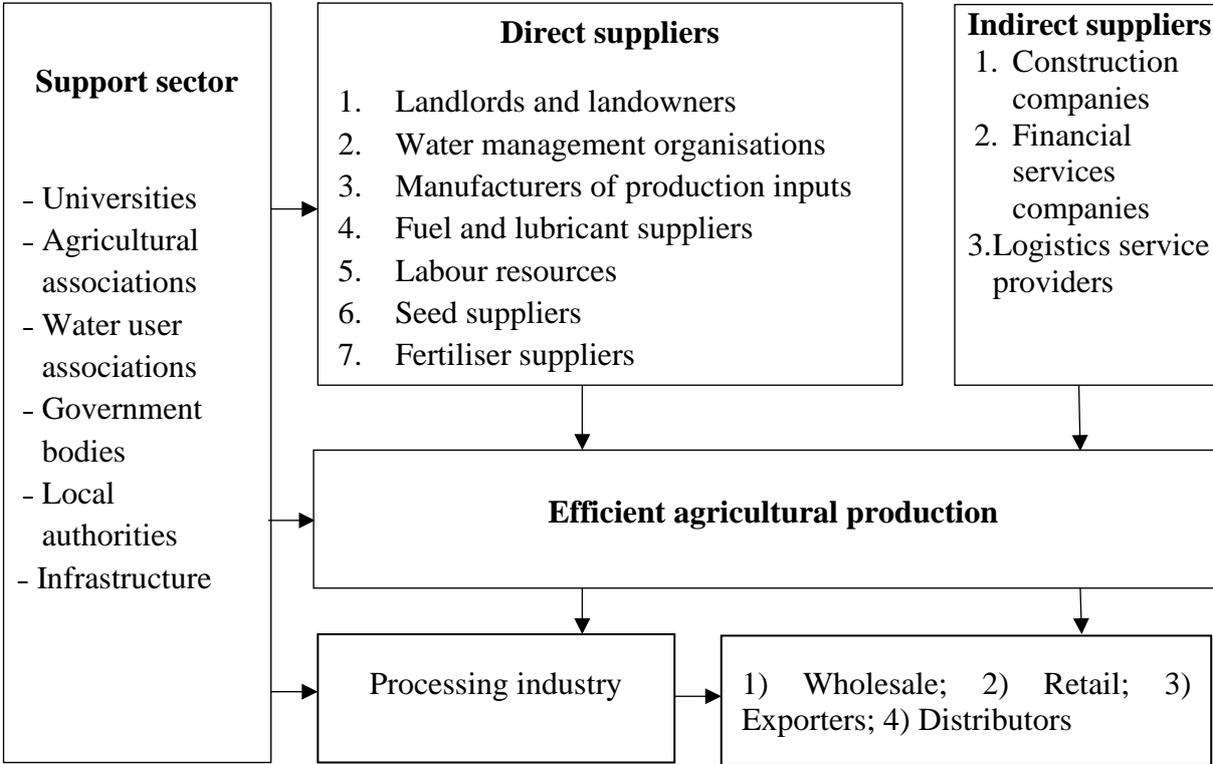


Fig. 3.5. Structure of clusters within European integration (prepared by the author)

When water and land resources are used jointly, internal efficiency increases, costs and business risks are reduced, information exchange improves and business management reaches a new, higher level, which significantly reduces transaction costs. The creation of functional mechanisms for the joint management of water and land resources therefore requires effective and inclusive governance at multiple levels, as well as coordinated and integrated policy measures across different sectors to address the numerous challenges associated with the use of natural resources, achieve the necessary compromises and preserve the state of the relevant ecosystems and their services. Multi-level governance mechanisms are essential to ensure the effectiveness, efficiency and inclusiveness of soil and water resource strategies. Multi-stakeholder and interdisciplinary approaches play a crucial role in creating a comprehensive land and water management system that involves civil society, academia, local communities, youth and the private sector.

CHAPTER 4. IMPLEMENTATION OF THE WATER FOOTPRINT CALCULATION METHODOLOGY IN THE CONTEXT OF CLIMATE CHANGE IN UKRAINE AND ON THE EXAMPLE OF ONE EU COUNTRY

4.1. Global trends in climate change

Climate change is one of the greatest threats to humanity, with far-reaching impacts on society, the environment and the economy. Climate change affects all regions of the world and all segments of the population.

According to reports by the World Meteorological Organisation, the average global temperature has already risen by 1.2 °C since 1850–1900. Depending on the volume of global greenhouse gas emissions in the coming years, it is estimated that the average global temperature will rise by between 1.5 and 4.3 °C above pre-industrial levels by the end of the 21st century [70].

The Paris Agreement sets the goal of keeping the global average temperature rise well below 2 °C compared to pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C, recognising that this would significantly reduce the risks and impacts of climate change [71].

According to a special report by the Intergovernmental Panel on Climate Change (IPCC) entitled Global Warming of 1.5 °C (2018), achieving the Paris Agreement goal of limiting the temperature increase to 1.5 °C is possible provided that the world reaches net-zero greenhouse gas emissions around 2050 (between 2045 and 2055), [71].

In order to meet the Paris Agreement targets, all countries need to take simultaneous action to reduce greenhouse gas emissions and adapt to the already existing impacts of global climate change.

Research suggests that without adaptation measures, climate change could reduce global agricultural growth by up to 30% by 2050. The 500 million small farms around the world will be the most affected. The number of people who do not have access to sufficient water for at least one month of the year will increase from 3.6 billion today to more than 5 billion by 2050 [72].

Rising sea levels and more frequent storms could displace hundreds of millions of people in coastal cities, and total losses in coastal urban areas could exceed \$1 trillion per year by 2050. Climate change could push more than 100 million people in developing countries into extreme poverty by 2030.

UN data shows that climate change will have devastating consequences for people living in poverty [72]. Even in the best-case scenario, hundreds of millions of people will face threats

to food security, forced migration, disease and mortality. In the long term, climate change threatens human rights and the progress made in global health and poverty reduction over the last fifty years. A continuation of these processes would be detrimental to the global economy and lead to a significant increase in poverty.

For many people, climate change has already become a new threat to their security. Between 2008 and 2024, 87% of internal displacement worldwide was caused by weather-related disasters rather than conflicts (Fig. 4.1), [73].

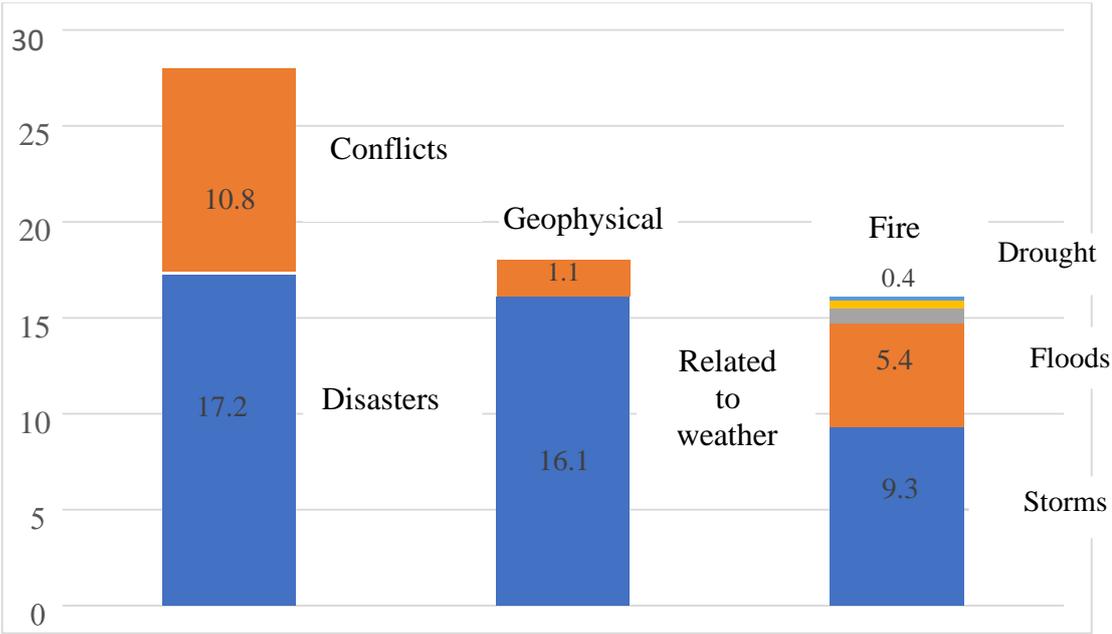


Fig. 4.1. Number of new refugees in 2024 for various reasons, in millions of people

A further temperature increase of 1.5 °C will only intensify and increase the frequency of such dangerous events. At the same time, climate change could cause more than 140 million people to become internally displaced in sub-Saharan Africa, South Asia and Latin America by 2050 [74].

Those who feel the most extreme effects of climate change are often the most vulnerable: two-thirds of the world’s most fragile states are highly exposed to climate change. At the same time, the world’s least developed countries receive only a fraction of global climate finance: of the USD 71.2 billion mobilised in 2017, less than 15% was allocated to them [75].

Furthermore, when the effects of climate change manifest themselves against a backdrop of weaker state efficiency or legitimacy, the risk of internal conflicts increases significantly. Although the impact of climate change on armed conflicts within states is

relatively small, it is expected to increase as global temperatures rise. The same applies to interstate conflicts, where climate change can lead to a shortage of vital natural resources.

In some parts of the world, warming has already exceeded 1.5 °C above pre-industrial levels. For example, in many areas of the Arctic, average temperatures have already risen by more than 3 °C [76]. This increases the risk of so-called climate tipping points. Once these thresholds are exceeded, environmental changes become irreversible, which in some cases can further accelerate climate change. For example, it is estimated that the Arctic permafrost region contains ten times more carbon than the Amazon rainforest. As warming progresses, frozen soil thaws and releases carbon dioxide into the atmosphere, further contributing to the greenhouse effect [77].

Over the last decade, greenhouse gas (GHG) emissions have increased by 1.5% per year, with a brief period of stabilisation between 2014 and 2016 [78]. Total annual GHG emissions, including land use change, reached a record high of 55.3 GtCO₂e in 2024. CO₂ emissions from fossil fuel combustion in the energy and industrial sectors, which dominate total GHG emissions, increased by 2% in 2024 to reach a record 37.5 GtCO₂e per year.

There is currently no evidence that global greenhouse gas emissions will peak in the coming years, and every year of delay means that deeper and faster emissions reductions will be needed. If emissions peak in 2024, they would need to be reduced by 25% or 55% by 2030 compared to 2022 levels in order to keep global warming below 2°C and 1.5°C at the lowest possible cost.

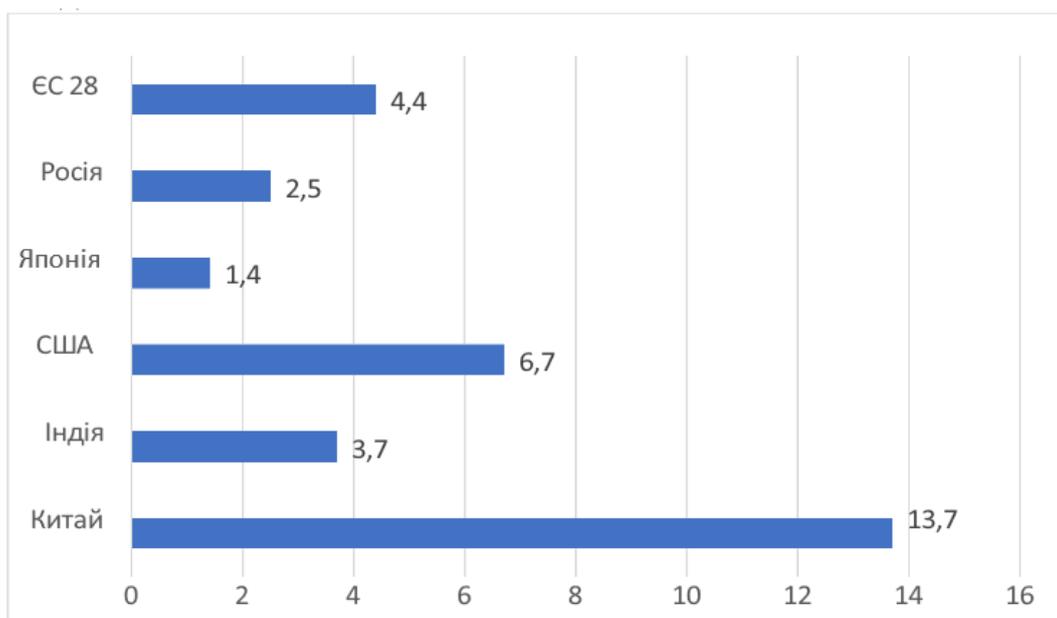


Fig. 4.2. Greenhouse gas emissions in 2024, Gt/year [70]

G20 countries account for 78% of global greenhouse gas emissions. Overall, they are on track to meet their limited 2020 commitments announced in Cancún, but seven countries are currently behind in meeting their intended nationally determined contributions (INDCs) for 2030, and the situation in three others remains uncertain. Strengthening climate action by G20 members will therefore play a key role in global efforts to mitigate the effects of climate change.

According to the World Meteorological Organisation, the five-year period from 2019 to 2023 was the warmest on record, with global temperatures rising 1.1°C above the pre-industrial level and 0.2 °C higher than in the previous five-year period [79]. Long-term and accelerating trends also dominated other key climate indicators, including sea level rise, Arctic sea ice loss, Antarctic ice loss, Greenland ice mass loss, and a clear decline in spring snow cover in the northern hemisphere [70]. Of all weather-related hazards, tropical cyclones, floods and landslides cause the most loss and damage. The most destructive events were Hurricanes Katrina (2005) and Harvey (2017), which caused economic losses of more than USD 125 billion.

Droughts exacerbate food insecurity in many regions and increase the overall risk of climate-related diseases. Rising sea temperatures threaten marine life and ecosystems as a whole. In addition, rising temperatures may jeopardise economic development due to their negative impact on the GDP of developing countries.

Achieving the 1.5°C target is still theoretically possible, but it requires global emissions to be reduced by 7.6% every year from 2030 onwards [80]. Any delay increases the scale of emissions reductions needed in the future. Despite compelling scientific evidence, however, some political leaders remain sceptical about the threat of climate change and the need for global action to adapt to it [81].

Compared to the current period, climate change is expected to increase the average annual temperature in Ukraine by 0.8-1.1 °C over the next 20 years (by 2040). These temperature statistics, presented in the Environmental Security and Climate Change Adaptation Strategy until 2030, are based on data from the World Meteorological Organisation and the World Bank report «Assessment of the Impacts, Opportunities and Priorities for Ukraine in the Context of Climate Change» (2021). At the end of the century, the temperature regime will remain within the limits of natural variability and will stabilise at the current level only if there is a significant reduction in anthropogenic impact on the climate system. In other scenarios, the average annual temperature will continue to rise, reaching 1.5–2 °C by mid-century and 2–4.3 °C by the end of the century.

Expected changes (°C) in average annual air temperatures in the 21st century in different

regions of Ukraine are shown in Table 4.1 [85].

Table 4.1

Expected changes (°C) in average annual air temperatures during the 21st century in different regions of Ukraine compared, [85]

Regions of Ukraine	Short-term outlook (2011–2040)	Medium-term outlook (2041–2070)	Long-term outlook (2071–2100)
Moderate scenario (low level)			
West	1.1	1.8	1.9
North	1.1	1.8	1.9
Centre	1.1	1.8	1.9
East	1	1.8	1.9
South	1.0	1.8	2.0
Medium scenario (medium)			
West	1.2	2.3	3
North	1.2	2.3	3
Central	1	2.3	3.2
East	1.2	2.4	3.3
South	1.3	2.4	3.4
High-end scenario			
West	1.3	2.8	4.5
North	1.4	2.9	4
Centre	1.4	2.9	4.6
East	1.4	3.0	4.7
South	1.4	3.1	4.9

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change highlights the urgent need for substantial and sustained decarbonisation and climate change adaptation measures in the area of food security. The projections in the report point to the negative impact of climate change on crop yields. In tropical and temperate regions in particular, a 2 °C increase in temperature without adaptation will have a negative impact on wheat, maize, soybean and rice yields, although some positive effects may also be observed in certain areas. A global temperature increase of 4 °C, accompanied by reduced water availability and increased competition for water resources, will become a major risk factor for global food security.

The general conclusions for Ukraine regarding climate change within four representative concentration pathways (RCPs) are as follows [85]:

– Warming is expected across the whole of Ukraine: approximately 1.65 °C in the steppe zone and 1.74 °C in the forest-steppe zone according to the RCP 4.5 scenario, and between 2.68 °C in the mixed forest zone and 2.98 °C in the steppe zone according to the RCP 8.5 scenario.

– Climate change will not have a significant impact on total precipitation. According to the RCP 4.5 scenario, precipitation changes will range from 13 mm in the steppe zone to 55 mm in the forest-steppe zone. Under the RCP 8.5 scenario, more significant changes are expected – more than 80 mm in the mixed forest zone and less than 13 mm in the steppe zone.

The largest decline in production by 2070 due to climate change is expected in the steppe zone: a likely decline in wheat production of 11% under the RCP 4.5 scenario and 18% under the RCP 8.5 scenario.

Currently, Ukraine's agricultural sector is not particularly sensitive to climate change. However, changes in weather conditions (higher air temperatures, uneven distribution of precipitation – often torrential during warm periods – and inefficient accumulation of soil moisture) are leading to an increase in the frequency and intensity of droughts. Combined with other negative factors of anthropogenic pressure, this may lead to the expansion of the zone of risky agriculture and desertification in the southern regions of Ukraine.

Intense warming in recent decades has led to changes in the structure of agricultural production, the area under arable crops and yield levels. Data show that the steppe zone, which accounts for 46% of the area under cereal crops, currently produces only 35% of total cereal production, compared to 45% in 1990. Despite a 21% increase nationwide, the average grain yield in this zone has fallen from 35.8 cent/ha in 1990 to 32.2 cent/ha in 2018-2023 over the last five years. In contrast, yields in the Polissia and forest-steppe zones increased from 30-37 cents/ha to 48-53 cents/ha, resulting in these zones producing 65% of total cereal production, even though they account for only 53% of the area under cereal crops [85].

In addition to significant territorial redistribution of crop structure, productivity growth dynamics and pace have become uneven. The average yield of cereals and legumes in the forest-steppe zone and Polissia increased by 46-61% compared to 1990, while in the steppe zone it decreased by 10%. A similar trend can be observed for other major crops. Overall, there has been an increase in cereal and legume yields in Ukraine thanks to regions with higher humidity [85].

If the current trend of increasing natural moisture deficit in arable land continues, by 2050 approximately 3 million hectares of arable land in the southern regions of Ukraine may become unsuitable for commercial crop production. As a result, taking into account the dehydration processes in the central and northern parts of the region, total cereal production may decline by 20–25% at the current level of agricultural technology. In the context of climate change, soil moisture availability is a key factor limiting agricultural productivity and the use of natural agricultural potential. To mitigate the negative effects of climate change on

agricultural production, it is necessary to implement the Irrigation and Drainage Strategy of Ukraine until 2030 [86].

There is a high probability that global warming will worsen climatic conditions on 2 million hectares of land. At the current rate of warming and with precipitation levels remaining virtually unchanged, parts of Ukraine, particularly parts of the Zaporizhia, Kherson, Mykolaiv and Odessa regions, may become unsuitable for agriculture within 10 to 15 years [87].

In the near future, both positive and negative consequences for agriculture will manifest themselves in different agroclimatic zones. The extension of the growing season will be a relatively favourable factor, especially for the Polissia region, while in the southern regions it will lead to an increase in dry periods. A study of the impact of climate change in various scenarios on the cultivation of major agricultural crops points to the following trends [88]:

- Over the next 10-20 years, favourable conditions for winter wheat production are expected to develop as a result of a 20-40 days and more efficient use of autumn growing conditions, which may lead to a 20-40% increase in overall productivity;

- In northern regions, sunflowers and maize will be planted for grain using more productive mid-season and late-season varieties.

- in the case of early spring cereals (barley, wheat, oats), the increase in temperature will cause a decline in yields due to a shorter growing season and earlier ripening;

- as the steppe zone shifts northwards into the modern forest-steppe zone, the northern limit of industrial cultivation of aubergines, sweet peppers and tomatoes will also shift, while the area suitable for growing potatoes, cabbage and cucumbers will shrink, requiring the implementation of pre-sowing measures.

In terms of agricultural productivity, climate change therefore has both positive and negative consequences. The positive effects include: improved conditions and shorter harvest periods; the possibility of effectively introducing late-maturing varieties (hybrids) that require more heat energy; improved conditions for overwintering crops and perennial grasses; increased fertilisation efficiency. Negative effects include: deterioration in grain quality due to increased carbon dioxide concentrations in the atmosphere; more frequent and severe droughts during the growing season; accelerated decomposition of humus in soils; deterioration of soil moisture in southern regions; insufficient vernalisation of cereals; increase in the number of pests, spread of plant disease pathogens and weeds due to favourable overwintering conditions; increased wind and water erosion of soil caused by more frequent droughts and extreme precipitation; higher risk of freezing of winter crops due to lack of stable snow cover during periods of significant temperature drops.

4.2. Recommendations for adapting agricultural management in Ukraine to climate change

At the end of 2020, 127 countries, responsible for approximately 63% of global greenhouse gas emissions, were considering or had already adopted climate neutrality targets to be achieved by 2060 at the latest. At the end of March 2021, Ukraine set its national target to achieve climate neutrality by 2060.

The European Union has also announced its intention to become climate neutral by 2050. This goal began to be actively discussed after the climate strikes that took place in 2019. In December 2019, the European Commission presented its vision for the future development of the European continent – the European Green Deal (EGD).

The European Green Deal is a package of systemic policy measures aimed at transitioning the European continent to climate neutrality by 2050 and creating a just and prosperous society. Although the EGD is not a law in itself, it is the first step towards introducing, at the legislative level, the efficient use of resources, green investments within initiatives, the reduction of greenhouse gas emissions and a just transition to sustainable development and environmental protection.

Ukraine is also part of the European continent, so the ambitions of the European Green Deal also apply to it. In this context, the environmental organisation Ecoaction (Екодія) has published its vision for Ukraine's involvement in achieving the EGD's goals.

The European Green Deal itself is only 24 pages long and is not exhaustive. However, it is supplemented by sectoral strategies covering key areas of development.

The key strategies of the European Green Deal for agricultural management of nature in the context of climate change are as follows [89]:

1. From farm to fork. Agricultural products such as sunflower seeds or poultry can absorb harmful substances during cultivation. The way agriculture is practised also damages the environment: it pollutes the soil and water, destroys forests to expand arable land and kills living organisms with insecticides. Some farmers add antibiotics to feed to accelerate animal growth and prevent the spread of disease. People who consume products from such farms become less or even completely resistant to antibiotics.

People should have free access to healthy food, and food production must not harm the environment. The Farm to Fork Strategy therefore aims to reduce pesticide use by 50% and fertiliser use by 20% while maintaining soil fertility at the same level. At the same time, the amount of products harvested per hectare should not be reduced.

In order to reduce the resistance of pathogenic bacteria to antibiotics, the strategy plans to reduce the sale of antibiotics to livestock and aquaculture farms by 50%. In addition, it promotes the development of environmentally friendly organic farming. Twenty-five per cent of agricultural land should be set aside for organic farming. All the strategy's targets must be achieved by 2030.

2. **Biodiversity.** More than half of global GDP – estimated at €40 trillion – depends on biodiversity. Therefore, the economic stability of countries directly depends on its preservation. For agricultural countries such as Ukraine, biodiversity is essential for survival. The loss of biodiversity threatens humanity by reducing the amount of plant and animal food, drinking water and medicinal resources.

To preserve biodiversity, the strategy recommends, in particular, increasing protected natural areas to 30% of the EU's land and marine areas and planting 3 billion trees by 2030. With regard to organic farming and reducing pesticide use, the recommendations of the biodiversity strategy are fully in line with the Farm to Fork Strategy.

The strategy also recommends restoring at least 25,000 km of free-flowing rivers in the EU and mobilising €20 billion per year to preserve and restore biodiversity.

3. **Climate Law.** The above strategies are effective but require adequate legislative support and financial incentives. The Climate Law aims to ensure this. It turns political promises into legal obligations. The Act sets a target of climate neutrality by 2050 and proposes a path to achieve it. This will ensure predictability, transparency and accountability towards European citizens and businesses – factors necessary for collective transformation.

Another condition for achieving the emission reduction target is maintaining economic competitiveness, using resources efficiently and building a fair and prosperous society.

4. **Adaptation.** The climate is changing and some changes are already inevitable, so adaptation is necessary. The updated strategy recommends smarter, faster and more systematic adaptation.

Adaptation to climate change is an integral part of the European Green Deal and is enshrined in the proposed European Climate Law. To ensure that the European Union adapts to the consequences of climate change by 2050, the strategy recommends:

- raising awareness of the impacts of climate change and the effects of adaptation decisions on well-being;
- thoroughly assessing climate risks;
- accelerating adaptation within the EU;
- helping to increase climate resilience worldwide.

The European Commission is set to finalise the strategy in June 2021.

In addition to the above strategies, the European Commission is developing a sustainable agriculture strategy that complements the objectives and mechanisms described in the other strategies.

The implementation of the European Green Deal poses challenges of varying degrees depending on the country and city. For example, the Norwegian capital Oslo and the Polish mining city of Katowice will have to expend different amounts of political effort and financial resources to become equally sustainable, climate-neutral and prosperous by 2050. *The Green Deal* is therefore *going local*. This does not mean that the Green Deal will have individualised requirements, but rather that the initiative will disseminate information on the successful implementation of its strategies and help regions overcome emerging challenges.

In October 2020, the Ukrainian government publicly announced its readiness to participate in the implementation of the European Green Deal and is continuing to develop a detailed plan for participation in this initiative. Ukraine is a signatory to the Paris Agreement and a member of the Energy Community Treaty, which commits it to implementing ambitious climate policies, adapting to climate change and ensuring sustainable agriculture.

It is therefore important to consider which strategic priorities for agricultural nature management in the context of climate change are key and should be included in Ukraine’s plan for participation in the EGD, in line with the positions of the European Green Deal and the recommendations of the IPCC (Tables 4.2, 4.3, 4.4).

Table 4.2

Climate targets and measures

Vision for Ukraine’s participation in the European Green Deal (EGD)	European Green Deal (EGD) [89]	IPCC recommendations [90]
1	2	3
<p><i>Climate neutrality in Ukraine by 2050.</i> Ukraine is committed to gradually reducing greenhouse gas emissions over the next 30 years. The second national contribution (NDC2) for 2030 should therefore set a target of reducing emissions by at least 73% compared to the 1990 baseline, ensuring a real reduction of 37% compared to 2010.</p>	<p>Climate neutrality across the European continent by 2050 [91]. Proposal for a European Climate Law, which enshrines the goal of climate neutrality by 2050 [92]. The EU NDC envisages a minimum 55% reduction by 2030 compared to 1990 [93]. In practice, this target means a reduction of current emissions by approximately 30%.</p>	<p>Achieving net-zero emissions by 2050 [94, 95]. Global net anthropogenic CO₂ emissions must fall by approximately 45% by 2030 compared to 2010 levels.</p>

continuation of the table 4.2

1	2	3
<p><i>Adaptation to climate change is integrated into sectoral objectives and strategies.</i></p> <p>National adaptation plans and NDC2 should be mutually reinforcing. Recognition of the priority role of nature-based solutions in all sectors where appropriate.</p>	<p>Climate change will affect all levels of society and all sectors of the economy, so adaptation measures must also be systemic [94, 95].</p> <p>The Commission will continue to integrate climate resilience considerations into all relevant policy areas.</p>	<p>Adaptation options selected according to national context and supported by favourable conditions will bring co-benefits for sustainable development and poverty reduction.</p>
<p><i>Financial mechanisms for reducing emissions</i></p> <p>Increase carbon taxation to a level that provides incentives to reduce greenhouse gas emissions and extend the list of taxable installations (below 500 t).</p>	<p>The EU will continue to support the development and implementation of adaptation strategies and plans at all levels of government with three cross-cutting priorities:</p> <ul style="list-style-type: none"> - integration of adaptation into macro-fiscal policy; - nature-based solutions; - • local adaptation measures. 	
<p>Reporting and transparency</p> <p>Transparent and reliable reporting of emissions from all sectors and companies, regardless of their size.</p>		

Table 4.3

Sustainable agricultural management of nature and the ‘farm to fork’ principle

Vision of the Ukrainian plan under the European Green Deal (EGD)	European Green Deal (EGD)	IPCC recommendations
1	2	3
<p><i>Reducing the impact of agriculture on climate change</i></p> <p>Reducing greenhouse gas emissions from agricultural land use</p> <p>The target for 2030 is zero emissions from land use (emissions balanced by absorption);</p>	<p>By 2030, at least 25% of EU agricultural land should be used for organic farming [96].</p>	<p>Reduction and/or prevention of greenhouse gas emissions through improved <i>land use management and practices</i> [97].</p> <p>Sequestration (absorption and retention) of greenhouse gases through terrestrial carbon and nitrogen sinks (soil, vegetation).</p>

continuation of the table 4.3

1	2	3
<p>By 2030, 15% of degraded arable land will be taken out of cultivation, and the area of pastures and meadows will increase to 15.8% of the country's land area.</p>		
<p><i>Reducing the environmental impact of agriculture</i> Introduction of management of agrochemical/fertiliser use, in particular collection and verification of data on the use of pesticides and agrochemicals by agricultural holdings and agricultural companies. <i>Reduction of the water and soil footprint of individual farms and economic sectors</i></p>	<p><i>Reduction of pesticide use</i> (chemical, more dangerous) by 50% by 2030. Primarily through promoting the use of safe alternative crop protection methods (crop rotation, mechanical weed removal, etc.); elimination of gaps in pesticide statistics.</p>	
<p>Updating the statistical information system to reflect the actual use of these substances; Harmonising the list of authorised plant protection chemicals with EU requirements; Stabilising (not increasing) and gradually reducing the use of agrochemicals and pesticides; Reducing losses of nutrients and active substances in environmental components (e.g. leaching from agricultural land into the aquatic environment).</p>	<p><i>Reduce nutrient losses</i> (nitrogen, phosphorus) by at least 50% while ensuring that soil fertility is not compromised. And reduce fertiliser use by at least 20% by 2030.</p>	<p>Replace fossil fuels for energy production with bio-products (waste, manure, other biomass).</p>
<p>Developing and further <i>increasing the share of organic farming</i> in order to reduce the burden on the environment. Reduction of food losses at all stages of the agri-food production chains and food waste in retail and households.</p>	<p>Plant health, seed safety and diversity, plant varieties adapted to climate change. Support for the creation of sustainable supply chains, <i>reduction of the environmental, water and soil footprint and consumption of energy in the production process, and appropriate product labelling</i>. Extension of requirements to products produced outside the EU.</p>	
<p><i>Sharing water and soil resources to ensure the ecological and economic security of agricultural management of nature</i></p>		

Table 4.4

Green finance, investment and just transition

Vision of the Ukrainian plan under the European Green Deal	European Green Deal (EGD)	IPCC recommendations
1	2	3
<p><i>Financing climate change mitigation and adaptation measures.</i></p> <p>Carbon tax should be used exclusively for climate change mitigation and adaptation measures through combating climate change and better ‘green’ practices.</p> <p>Continued support from national and local budgets for climate change mitigation and adaptation measures.</p>	<p>Expanding international climate resilience financing:</p> <ul style="list-style-type: none"> · Efforts to increase international financing for climate change adaptation measures through EU external action instruments and the use of private sector investment. · Supporting the development and implementation of disaster risk financing strategies to increase resilience. · macroeconomic environment in partner countries; · support partner countries in developing policies and incentives to promote climate-resilient investments, including investments in nature-based solutions; · strengthening the climate change resilience of all EU external investments and actions. 	
<p><i>Business based on social responsibility principles</i></p>	<p>EU Member States with coal regions are developing separate ‘territorial just transition plans’ [98].</p>	<p>Social justice and equality are key aspects of the path to achieving the 1.5 °C scenario</p>
<p><i>Supporting the sustainable use of agricultural land</i></p> <p>Support for small and medium-sized producers, provided they use sustainable agricultural practices.</p> <p><i>Ending subsidies for vertically integrated agricultural enterprises (agricultural enterprises).</i></p>	<p>Tax incentives for the transition to a sustainable food system and encouraging consumers to adopt a sustainable and healthy diet. By regulating VAT rates, Member States can specifically promote, for example, organic production [2 31].</p> <p><i>EU tax systems should also aim to ensure that the prices of different food products reflect their true costs in terms of the use of limited natural resources, pollution and the soil and water footprint.</i></p>	

1	2	3
	<p>Through EU budget guarantees, the InvestEU Fund will facilitate investment in the agri-food sector by reducing the investment risk for European companies and facilitating access to finance for small and medium-sized enterprises. The EU’s Common Agricultural Policy (CAP) should also increasingly contribute to supporting investments to increase resilience and accelerate the green and digital transformation of farms.</p>	

Climate change poses a conceptual challenge for water resource managers, as it brings uncertainty to future hydrological conditions. In most cases, adaptation decisions will need to be taken before it is clear how hydrological regimes will actually change. It is therefore considered appropriate to apply a scenario-based approach to water resource management in the context of climate change. This approach is already being applied in practice in developed countries around the world. A second approach to addressing uncertainty, known as ‘adaptive management’, involves increased use of resources for water management measures that are relatively resilient to uncertainty. Such measures include, for example, actions to reduce water demand, which help to minimise the impact of climate change. Water management responses to climate change may include the development of new approaches to system assessment and design, as well as non-structural methods based on mechanisms such as the EU Water Framework Directive.

A distinction is often made between autonomous and planned adaptation. Autonomous adaptation refers to adaptation that is not a conscious response to the impacts of climate change, but is the result of adjustments aimed at meeting changing needs, new tasks and expectations which, although not specifically designed to address climate change challenges, may help to mitigate the impacts of climate change.

Planned adaptation is the result of deliberate policy decisions and explicitly addresses climate change and climate variability, but has been implemented relatively rarely to date. Water resource managers in several countries – including the Netherlands, Australia, Germany, the United States and Bangladesh – have begun to directly address the impacts of climate change as part of their routine flood management and water supply planning. Such adaptation

is typically implemented through changes in methodologies and regulations, such as design standards or climate-sensitive technical regulations.

Autonomous adaptation options mainly involve expanding or intensifying existing risk management and productivity enhancement activities and are therefore already available to agricultural enterprises. In relation to water resources, they include:

- the selection of crops with greater resistance to temperature shocks and drought;
- changes in irrigation practices, including volume, timing or technology;
- the development and implementation of efficient water technologies to capture water, conserve soil moisture (e.g. crop residue retention) and reduce siltation and saltwater intrusion;
- improved water management to prevent waterlogging, erosion and nutrient leaching;
- adjustments to cropping calendars, i.e. timing or geographical location of cultivation.

Other adaptation strategies may include changes in land use that take into account new agroclimatic conditions.

Planned adaptation strategies should focus on developing new infrastructure, programmes and institutions that will support, encourage, coordinate and maximise the benefits of new management practices and land use models. This can be achieved in particular through improved governance, including the integration of climate change considerations into development programmes, increased investment in irrigation infrastructure and water-efficient technologies, the provision of adequate transport and storage infrastructure, and the revision of land use planning.

Coordinated adaptation strategies and policy alignment across multiple institutions may be needed to facilitate adaptation to climate change, particularly where declining productivity – negatively affecting low-yield farming – encourages the adoption of inappropriate agricultural practices, thereby increasing not only soil degradation but also resource consumption, including water.

Technological development opportunities through expanded research and development include traditional breeding and biotechnologies aimed at increasing the resilience of agricultural and fodder crops, livestock, forest plantations and fisheries to climatic stresses such as droughts and floods.

Water management organisations that set standards for water use will play a key role in managing social tensions arising from changes in water availability, as well as in distributing benefits and losses among different sectors of society. Public institutions should seek more efficient ways of allocating water, applying principles such as fairness and efficiency. These

parameters should also include the management of international river basins as well as surface and groundwater resources.

To mitigate the additional stress caused by climate change, public participation in water use planning is essential – particularly with regard to the perception of the value of water, the importance and future role of water reuse, and the level of contribution that society is willing to make to mitigate water-related impacts.

In order to implement policies based on the principles of integrated water resources management, it is necessary to improve coordination between different government bodies and analyse institutional and legal frameworks with a view to facilitating the implementation of adaptation measures.

Climate change will affect all stakeholders involved in water management, including water users. Therefore, all stakeholders must be informed about the potential impacts on the system so that they can make appropriate decisions and be prepared to bear the associated costs.

Adaptation to changes in water availability and quality should be implemented not only by water management organisations, but also by individual water users. Integrated water use should become a tool for determining measures to adapt to climate change, although this tool is currently still in its early stages of development.

4.3 . Methodology for assessing virtual water use with regard to climate change in Ukraine

The availability of sufficient quantities of high-quality fresh water is a fundamental condition for the development of human society and natural ecosystems. In many parts of the world, excessive consumption of fresh water and pollution caused by human activity are putting enormous pressure on water availability, food security, water quality, economic development and the social well-being of the population. The current challenges associated with freshwater scarcity may intensify as a result of growing demand for water resources and a decline in their availability and quality. Researchers argue that humanity's dependence on water resources will increase in the future, which may threaten food security and the environmental sustainability of natural resources [100–104].

Traditionally, total water consumption and pollution have been assessed in terms of the total volume of water needed to sustain life. Much less attention has been paid to water issues arising from the structure of the global economy, which produces a wide range of goods and services. As a result, there is almost no information available on how production characteristics and logistics chains significantly affect water consumption (spatial and temporal distribution of

water resources) and pollution. Visualising hidden water consumption throughout the life cycle of products can contribute to understanding the global nature of freshwater consumption and trade, as well as their impact on the quantity and quality of water resources. This, in turn, enables informed strategic decision-making to improve water management – both at the level of individual production processes and at the regional, national and global levels.

The concept of virtual water was first introduced by British ecologist John Allan [236], who defined it as the volume of water required to produce a good or provide a service. A related term – water footprint (WF) – was later proposed by Professor Hoekstra of the University of Twente [105]. This tool allows not only quantitative assessment, but also assessment of qualitative indicators.

The water footprint shows how, when and where freshwater resources are used. It is a comprehensive indicator that allows the spatial and temporal distribution of water resource use to be assessed. There are three types of virtual water, or components of the water footprint:

1. Green water – rainwater stored in the soil that is used and evaporates during the production process, especially during crop cultivation.
2. Blue water – surface or groundwater taken from rivers, lakes or water sources and consumed (i.e. evaporated, incorporated into a product or not returned to the same water body).
3. Grey water – the volume of water needed to assimilate pollutants generated during production so that the resulting water meets the specified water quality standards [106].

The overall structural elements of the water footprint are shown in Fig. 4.3 [106].

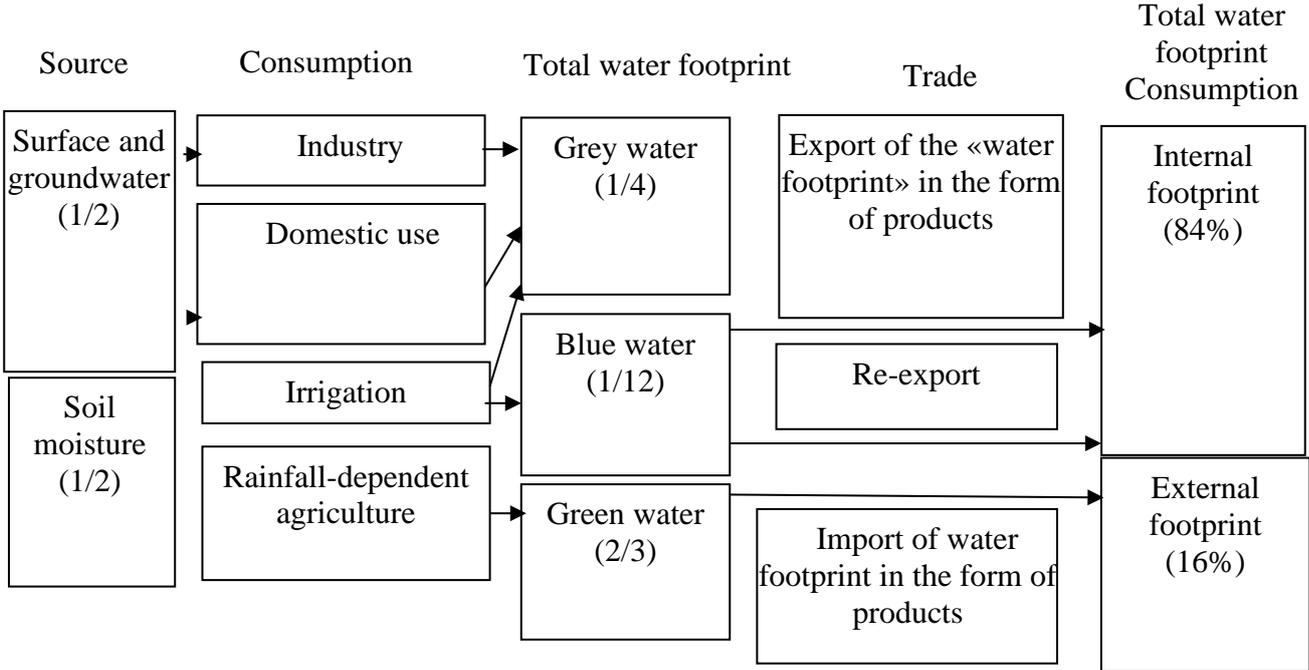


Fig. 4.3. Components of the «water footprint» [106]

Water footprint assessment is a simple but effective concept that allows us to:

- understand the geographical distribution of water resources for industry, agriculture and domestic water supply;
- assess the efficiency of water use, including consumption and pollution;
- determine the sustainability of water resource use, such as the level of water scarcity, water pollution and related social and economic challenges;
- identify the most appropriate strategic measures to increase sustainability, efficiency and responsibility in water use.

The water footprint is therefore a tool that allows for a broader and more comprehensive assessment of how consumers or producers interact with freshwater systems. It is an integrated indicator that allows the calculation of water consumption and water pollution volumes in all qualitative components. It is not an indicator of local environmental impact, as such impact depends on the vulnerability of the local water ecosystem and the amount of water consumed by consumers and polluters of the freshwater system. The water footprint tool provides accurate information on how water is used for different purposes. It serves as a basis for drawing conclusions about the sustainable and equitable use and distribution of water resources and is also the basis for assessing environmental, social and economic impacts.

«Water footprint assessment» includes a range of activities related to: (I) quantifying the water footprint of a process, product, producer (consumer) or the spatial and temporal distribution of water resources within a specific geographical area; (II) assessing the environmental, social and economic sustainability of the water footprint; (III) formulating a strategy to address the identified challenges (Fig. 4.4).

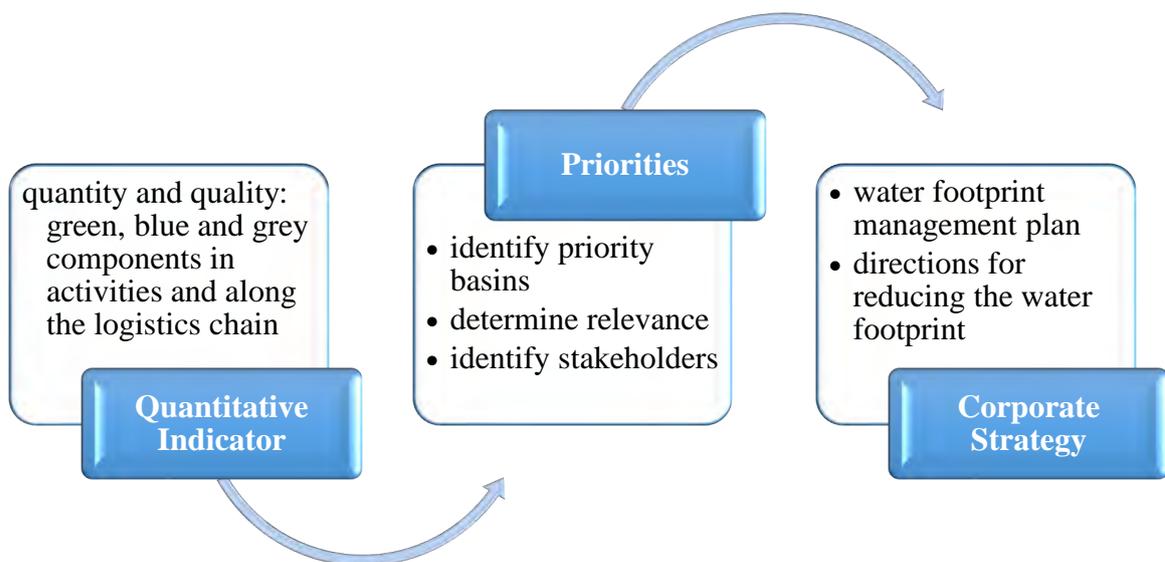


Fig. 4.4 . Water footprint assessment of businesses

The main objective of water footprint assessment is therefore to analyse human activities or justify the production of specific goods in terms of water scarcity and water pollution, and to formulate water policies that ensure the sustainable use of virtual water flows.

The water footprint is an analytical tool that plays a key role in understanding the relationship between economic activities and products on the one hand and water scarcity and environmental pollution on the other. It creates the conditions for assessing the consequences of anthropogenic impacts and for informed decision-making on the rational use of freshwater resources. The overall assessment of the water footprint is carried out in four separate stages (Fig. 4.5), [106–117].

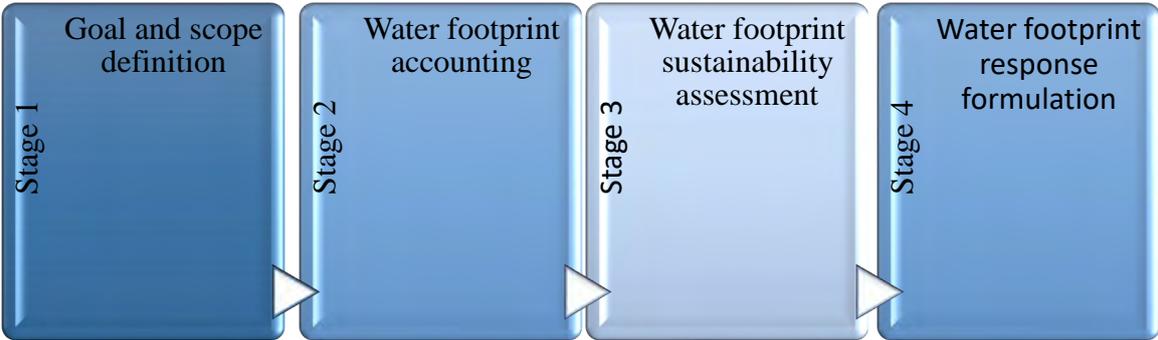


Fig. 4.5. Stages of water footprint assessment

To ensure transparency in the water footprint assessment process, it is important to first clearly define the objectives and scope of the required research. Water footprint studies can be designed to identify the impact of various factors. For example, a government may be interested in determining external water dependencies or assessing the sustainability of water use in a region where water-intensive products, including green goods, are imported on a large scale. A river basin authority may want to determine whether the total water footprint of anthropogenic activities in the basin violates environmental flow requirements or water quality standards, or to what extent a water-scarce basin produces low-value agricultural commodities for export. A company may seek to identify its dependence on scarce water resources within its supply chain or assess how this dependence affects the mitigation of negative impacts on aquatic ecosystems within its own operations.

The second phase – calculating the water footprint – involves collecting data and performing all necessary calculations. The scope and level of detail of the calculation framework depend on the decisions made in the previous phase. The calculation is followed by

a sustainability assessment, during which the water footprint is evaluated from an environmental, social and economic perspective.

In the final phase, response options will be developed and subsequently incorporated into the formulation of water strategy or policy.

The water footprint assessment does not necessarily have to include all of the above steps. Depending on the objectives and scope, the study may focus exclusively on virtual water accounting or only on sustainability assessment, leaving open the question of identifying bottlenecks in the freshwater system. Furthermore, in practice, this WF assessment model serves as a guideline rather than a strict directive.

Blue water sources are usually scarce and have higher costs compared to green water, which has led most researchers to focus only on calculating the blue water footprint. However, green water can be replaced by blue water, especially in organic farming, where efficiency is significantly influenced by climatic factors. Therefore, a complete picture can only be obtained if both components are taken into account. Another argument in favour of including green water use is the fact that historically, the emphasis on blue water has led to an underestimation of the role of green water (Falkenmark), [117].

When we look at the product life cycle, it is clear that supply chains are endless and vary significantly in terms of the inputs used at each stage of the process. In practice, however, only a few stages contribute significantly to the overall water footprint of the final product. As a rule, if a product contains individual components originating from agricultural production, these components often account for the majority of the product's water footprint. Experts estimate that 86% of humanity's water footprint is attributable to the agricultural sector (Hoekstra and Chapagain), [118].

An analysis of water footprint assessment methodologies depending on scope and location is presented in Table 4.5 [119, 120].

The minimum spatial resolution for small river basins is approximately 100–1,000 km², but if necessary and if the data allow, calculations can be performed at the local level. In the latter case, this applies to the calculation of the water footprint of organic farms, districts or sectors (levels B and C).

The minimum time period for calculations is one month, and the assessment includes an analysis of interannual variability. Accounting is based on best estimates of actual local water consumption and environmental pollution levels.

Analysis of water footprint assessment methods

Level	Spatial Explanation	Temporary explanation	Water consumption data	Typical water footprint assessment methodology
Level A	Global	Annual average	literature sources and databases on typical water consumption and pollution levels during product manufacturing	raising awareness; rough identification of components of the total water footprint; performing global water consumption forecasts
Level B	national, regional, specific river basins	annually by month	literature sources and databases on typical water consumption at national, regional or river basin level	rough identification of the spatial and temporal distribution of water consumption; identification of main problem areas; support for decision-making on water allocation
Level C	small river basins or specific fields	monthly by day	Empirical data; database on water consumption and pollution levels environment in a specific location	knowledge base for detailed assessment of water footprint and sustainability evaluation; formulation of strategies to reduce the water footprint resulting from local impacts

Note: These three levels can be distinguished for all forms of water footprint calculation (e.g. calculations at product, country, and company level).

Either a specific year or a series of years is selected for water footprint calculations, but alternatively, average values reflecting prevailing climatic conditions (e.g. a 30-year average) may be used.

As agriculture in general and organic production in particular are water-intensive sectors, organic products often have a significant water footprint.

Water footprint assessment can be applied to both annual and perennial crops (trees can be considered perennial crops). In the following text, the term ‘crop’ is used in a broad sense.

The total water footprint of organic crop and tree cultivation (WF_{proc}) is the sum of the green, blue and grey components and is calculated according to the formula [114]:

$$WF_{proc} = WF_{proc,green} + WF_{proc,blue} + WF_{proc,grey} \quad (4.1)$$

All water footprint indicators are expressed per unit of production, i.e. in volume of water per weight of agricultural production (m^3/t), which corresponds to l/kg .

The blue water footprint characterises the use of blue water, i.e. surface and groundwater. The use of virtual blue water includes [120]:

- the volume of water that evaporates from the surface in the river basin;

- the volume of water contained in the product;
- the volume of water that does not return to the same river basin;
- the volume of water that does not return during the same period (e.g. water used during periods of water shortage and released during periods of rainfall).

The first component – evaporation – is usually the most significant. Therefore, water consumption is often equated exclusively with evaporation; however, in our opinion, the other three components must also be taken into account when estimating blue water volumes.

Throughout the year, surface water and groundwater can be used for irrigation, industrial or domestic purposes, although consumption cannot exceed the amount available during a given period. The blue water footprint defines the amount of water available for consumption during a given period (i.e. water that does not immediately return to the same river basin). This corresponds to the volume of available water resources. The remaining groundwater and surface streams that are not affected by human activity remain in the ecosystem and support its functioning.

The blue water footprint of organic farming is calculated as follows:

$$WF_{proc,blue} = \text{Blue water}_{evaporation} + \text{Blue water}_{product} + \text{Unused return flow [volume/time]} \quad (4.2)$$

The last component refers to the proportion of return flow that cannot be reused in the same river basin or that returns to another river basin or at another time.

When assessing the blue water footprint of agricultural production, it may be appropriate (depending on the scale) to distinguish blue water by source type. The most common classification distinguishes between surface and groundwater sources. In practice, this distinction is often difficult to make due to insufficient data. However, if available, the blue water footprint can be broken down by source [120, 121].

The green water footprint measures the use of green water – precipitation temporarily stored in the soil or vegetation, which eventually evaporates or is consumed by plants. The green water footprint of organic production is calculated as:

$$WF_{proc,green} = WF_{green,vol.} + WF_{green,consumption} \quad (4.3)$$

The difference between the blue and green water footprints is important because these components have different hydrological, environmental and social consequences. For example,

the economic losses associated with the use of surface and groundwater in agriculture differ significantly from the consequences of rainwater use.

The green water footprint in agriculture can be measured or estimated using empirical formulas, crop growth models and soil water balance models based on climate, soil and plant data.

The green water footprint of organic crop production ($WF_{proc,green}$, m³/t) is calculated as the volume of green water consumed by crops (CWU_{green} , m³/ha) divided by yield (Y , t/ha):

$$WF_{proc\ green} = \frac{1,09 * CWU_{green}}{Y} \quad (4.4)$$

The blue water footprint ($WF_{proc,blue}$ m³/t) is calculated similarly:

$$WF_{proc\ blue} = 1,09 * \frac{CWU_{blue}}{Y} \quad (4.5)$$

According to a study conducted by the Institute of Water and Reclamation Problems (IVPiM) of the National Academy of Agricultural Sciences, an increase in average monthly air temperatures of 1 °C (without taking other factors into account) leads to a 9% increase in potential total monthly evaporation [122]. Since average temperatures in Ukraine are expected to rise by 1 °C by 2040 (see Table 7.1), it is appropriate to introduce a coefficient of 1.09 into the formulas for calculating the green and blue water footprints at the national level (without regional differentiation) to account for increased evaporation.

In addition, we have specified the specific values of the green water footprint depending on regional distribution and different climate change scenarios (mild, moderate, severe) for the period up to 2040.

Statistical data can be used to determine the yield of annual organic crops. In the case of perennial crops, the average annual yield over the entire life cycle must be taken into account, as yields during the initial transition to organic production may be very low or zero. The average annual water consumption during the crop life cycle is also averaged.

The green and blue components of the water footprint in organic farming (CWU , m³/ha) are calculated as the sum of daily evapotranspiration (ET , mm/day) using crop growth models and soil water balance models [114, 117].

Evapotranspiration of green and blue water during organic crop cultivation can be calculated using the CROPWAT model developed by the Food and Agriculture Organisation of the United Nations (FAO), [123, 124].

The model offers two alternatives. The simplest – though not the most accurate – is the ‘CWR option’. This option assumes that there are no constraints on meeting crop water requirements. The model calculates the following: crop water requirements (CWR) throughout the growing season under specific climatic conditions; effective precipitation for the same period; irrigation requirements.

Under this option, it is assumed that ideal conditions for organic crop growth are ensured from planting to harvest. ‘Ideal conditions’ means that precipitation and/or irrigation maintain adequate soil moisture so that crop growth is not limited and the planned yield of organic crops is achieved.

The water requirement for an organic crop is calculated by multiplying the crop reference evapotranspiration (E_{To}) by the crop coefficient (K_c):

$$CWR = K_c \times E_{To} \quad (4.6)$$

It is assumed that the water requirements of organic crops are fully satisfied, so that the actual crop evapotranspiration (E_{Tc}) is equal to the amount of water needed to support organic yields:

$$E_{Tc} = CWR \quad (4.7)$$

Reference crop evapotranspiration (E_{To}) represents the rate of evapotranspiration from a reference surface without water restrictions. The reference crop is a hypothetical surface covered with well-irrigated green grass with standardised properties. Climatic parameters are therefore the only factor influencing E_{To} . E_{To} reflects the evaporation demand in a given region and season and does not take into account crop or soil properties.

Evapotranspiration under ideal conditions differs from actual crop evapotranspiration because the aerodynamic properties and surface resistance of field crops differ from those of reference grass. The crop coefficient (K_c) integrates these properties and takes into account the differences between field crops and the reference surface. The crop coefficient changes during the crop growth phases.

The K_c value for different crops during the ecological cultivation period is determined based on literature sources (e.g. Allen et al.), [125]. K_c can also be calculated as the sum of K_{cb}

and K_e , where: K_{cb} is the basal crop coefficient, defined as the ratio of crop evapotranspiration to reference evapotranspiration (ET_c/ET_o) under conditions where the soil surface is dry but plant transpiration is proceeding at its potential rate; K_e is the soil evaporation coefficient. Therefore, $K_{cb} \times ET_o$ represents the transpiration component of ET_c , while ET_c also includes the soil evaporation component.

An alternative to CROPWAT is AQUACROP [126], a crop growth model that more accurately simulates yield under water stress conditions and separately considers the K_{cb} and K_e coefficients.

Effective precipitation (P_{eff}) is the portion of total precipitation that is stored in the soil as potentially available water to meet the needs of organic crops. This value is often lower than total precipitation because not all precipitation can be actually used by plants (e.g. due to surface runoff or deep percolation). Several approaches can be used to estimate effective precipitation.

Irrigation requirement (IR) is calculated as the difference between crop water requirement and effective precipitation. Irrigation requirement is zero if effective precipitation exceeds crop water requirement (Formula 4.8):

$$IR = \text{Max} (0, CWR - P_{eff}) \quad (4.8)$$

Green water evapotranspiration (ET_{green}), i.e. the part of crop evapotranspiration supplied by precipitation, depends on the amount of precipitation. It is defined as the minimum of total crop evapotranspiration (ET_c) and effective precipitation (P_{eff}). Blue water evapotranspiration (ET_{blue}), evapotranspiration from irrigation, is defined as total crop evapotranspiration minus effective precipitation. When effective precipitation exceeds total crop evapotranspiration, blue water evapotranspiration is zero:

$$ET_{green} = \min (ET_c , P_{eff}) \quad (4.9)$$

$$ET_{blue} = \max (0, ET_c - P_{eff}) \quad (4.10)$$

All water flows are expressed in mm/day or mm/period.

The grey water footprint of organic farming is an indicator of the level of freshwater pollution. It represents the volume of freshwater needed to dilute pollutants to natural concentrations and to meet national or global surface water quality standards.

In organic farming, water pollution is minimal because this farming system prohibits the use of mineral fertilisers (except organic ones), herbicides, pesticides and other agrochemicals. The main natural pollutant is nitrogen from organic fertilisers.

The grey water footprint is calculated by dividing the pollutant load (L , in weight/time) by the difference between the water quality standard for a specific pollutant (maximum permissible concentration C_{max}) and its natural concentration in the receiving water body (C_{nat}).

$$WR_{proc\ grey} = \frac{L}{c_{max}-c_{nat}} \quad (4.11)$$

The natural concentration of a water body is the concentration that occurs in it without any anthropogenic load. For man-made substances that do not occur naturally in water bodies, this value is set at 0. If natural concentrations are not precisely known but are estimated by experts to be very low, they may also be considered to be 0 for the sake of simplifying the calculation.

The grey water footprint serves as an indicator of the assimilation capacity of the freshwater system. Concentrations of pollutants in surface waters are usually determined for environmental protection purposes. The grey component of the water footprint of organic farming ($WF_{proc, grey}$, m³/t) is calculated as the product of the amount of organic fertiliser applied to the field (AR , kg/ha) and the leaching and runoff fraction (a), divided by the difference between the maximum permissible concentration of the pollutant (c_{max} , kg/m³) and its natural concentration in the receiving water body (c_{nat} , kg/m³), taking into account the relevant crop yield (Y , t/ha):

$$WR_{proc\ grey} == \frac{(a \cdot AR)/(c_{max}-c_{nat})}{Y} \quad (4.12)$$

When calculating the grey water carbon footprint, only the volumes of wastewater entering freshwater bodies shall be taken into account.

Given that humanity is currently facing a growing shortage of fresh water of adequate quality, attention must be paid to the efficient use of water resources in agriculture in general and in organic farming in particular. It is advisable to develop a clear system for monitoring, controlling and accounting for water resources, to establish responsibility for excessive water use, and to develop mechanisms and tools that will allow total water consumption to be reflected in the price of products using the water footprint methodology. Under such conditions, producers will be motivated to use water resources rationally.

The economic efficiency of water use in agricultural production (thousand UAH/m³) represents the economic value of agricultural products per unit of water consumed. It is calculated as *the average production price* p (thousand UAH/t) recommended by the FAO,

multiplied by a coefficient β that reflects the high quality of agricultural products, and divided by the sum of the green and blue water footprints:

$$E = \frac{\text{price } [p] \times \beta}{WF_{proc\ green} + WF_{proc\ blue}} \quad (4.13)$$

This methodology allows both the high quality of agricultural products and all water resource costs incurred during production to be included in the price of the product. It justifies the use of water resources in the context of climate change through modern global approaches, thereby ensuring the food and environmental security of the systems analysed.

4.4 Comparative assessment of water resource use in Ukraine and Poland in agricultural management with nature

In order to assess the effectiveness of strategic decisions regarding the use of water resources in the agro-industrial complex, we compare Ukraine with a similar country. Poland was selected for this purpose. This country is similar in terms of the volume of renewable water resources, geographical location, and natural and climatic conditions. Poland belongs to a group of European countries whose water resources should be considered insufficient. On average, one inhabitant has three times less water compared to the average level in European countries. In addition, water resources in Poland are unevenly distributed across the country. Most of Poland's territory is located in the basins of two large rivers: the Vistula and the Oder. The Oder is one of the rivers with the highest probability and intensity of flooding according to European standards.

Comparative characteristics of Ukraine and Poland are presented in Table 4.6.

Although Ukraine is twice the size of Poland in terms of territory, both countries have almost the same volume of internal renewable water resources. However, Ukraine receives six times more external surface water.

Similar to Poland, Ukraine is among the countries with low water availability. Average long-term renewable water resources are estimated at 120.21 km³ per year, which corresponds to 1.2 thousand m³ per person per year.

At the same time, available surface and groundwater resources are unevenly distributed across the country. More than half of Ukraine's water resources are concentrated in the Dniester River basin, where water demand does not exceed 5%.

Table 4.6

Comparative characteristics of Poland and Ukraine

Indicator	Region	
	Poland	Ukraine
Total population, millions of people	38,612	44,824
Area (1,000 hectares)	31,268	60,355
Long-term average annual precipitation ($10^9 \text{ m}^3/\text{year}$)	187.6	341
Internal surface water in the country ($10^9 \text{ m}^3/\text{year}$)	53	50.1
Internal groundwater in the country, ($10^9 \text{ m}^3/\text{year}$)	12	22
Total internal renewable water resources (IRWR), ($10^9 \text{ m}^3/\text{year}$)	53.6	55.1
Total domestic renewable water resources per capita ($10^3 \text{ m}^3/\text{capita}/\text{year}$)	1,388	1,229
External surface water entering the country (total) ($10^9 \text{ m}^3/\text{year}$)	6.9	36
External groundwater entering the landscape (total), ($10^9 \text{ m}^3/\text{year}$)	0	0
Total external renewable water resources, ($10^9 \text{ m}^3/\text{year}$)	6.91	120.21
Total renewable water resources per capita ($10^3 \text{ m}^3/\text{capita}/\text{year}$)	1,567	3,911

**AQUASTAT database [127]*

In dry years, water shortages are observed almost everywhere, especially in the basins of the Lower Dnieper, Siverskyi Donets, Southern Bug, Ingul and in the Azov Sea area, etc. The potential of Ukraine's groundwater resources is almost 22 km³ per year. The total amount of explored groundwater reserves available for use is approximately 5.7 km³ per year, with actual withdrawal amounting to 2.5 km³ per year. The total volume of water withdrawn from natural water resources in recent years has been 15.7 km³ per year, of which 48% is used by industry, 26% by agriculture and 25% by municipal services. Currently, the Ukrainian economy is characterised by low efficiency in the use of natural resources and high water intensity of GDP (on average 0.3 m³ of water per 1 hryvnia of finished products), [128].

An alternative approach to reducing water consumption in Ukraine could be a strategy aimed at minimising domestic water consumption by importing water-intensive products, both agricultural and industrial. The water situation in a water-scarce region can be significantly improved by importing goods whose production requires large amounts of water, instead of producing them domestically, i.e. by importing virtual water.

A comparative analysis of virtual water flow generation in Ukraine and Poland is presented in Table 4.7.

Table 4.7

Analysis of virtual water flow generation, millions of m³/year

Indicator	Region	
	Poland	Ukraine
1	2	3
<i>Virtual water imports</i>		
Agricultural products, including:		
ecological water footprint	11,501.5	4585.8
blue water footprint	2229.6	677.3
Grey water footprint	1121.7	347.6
Animal products, including:		
Ecological water footprint	715.6	349.3
blue water footprint	77.5	26.1
grey water footprint	64.7	19.3
Industrial products, including:		
blue water footprint	223.1	154.6
grey water footprints	2870.2	2750.0
<i>Virtual water exports</i>		
Agricultural products, including:		
ecological water footprint	3946.3	15289.2
blue water footprint	909	545.6
grey water footprint	881.2	691.4
Animal products, including:		
ecological water footprint	2569.4	2303.6
blue water footprint	230.3	227.5
Grey water footprint	195.2	78
Industrial products, including:		
Blue water footprint	268.6	292.5
grey water footprints	2471.2	5888.6
<i>Total virtual water flow</i>		
Imports		
Green water footprint	12,217.1	4935.1
Blue water footprint	2530.1	858.1
grey water footprint	4056.7	3116.9
Export		
Green water footprint	6515.7	17,592.8
blue water footprint	1407.9	1065.7
Grey water footprint	3547.7	6658.0
Net virtual water imports		
Green water footprint	5701.4	-12658
Blue water footprint	1122.2	-
grey water footprint	509	-3541.1

*Compiled based on [129]

In total, 16% of the water used for agricultural and industrial production worldwide is exported as virtual water, with the annual global flow of virtual water estimated at approximately 1.6 million m³ per year.

In general, countries that import virtual water are those with limited water resources (less than 5,000 m³ per capita). Countries with sufficient or abundant water resources, i.e. more than 25,000 m³ per capita, tend to export the virtual water contained in agricultural and industrial products. Ukraine and Poland are countries with low water availability, and therefore their national policies should support the import of virtual water.

If we compare these two countries (Table 4.7), we find that despite approximately the same level of virtual water imports, Ukraine – unlike Poland – exports almost four times more virtual water in the form of agricultural products, which ultimately leads to negative net virtual water imports for the country. This situation («less is more») threatens the water and food security of the Ukrainian agricultural sector and requires an urgent review of strategic priorities in the field of agricultural nature management.

CHAPTER 5. DEVELOPMENT OF THEORETICAL AND METHODOLOGICAL PROVISIONS AND THE CONCEPT OF THE «LAND FOOTPRINT»

5.1. Analysis of methodologies for assessing resource use and resource efficiency based on footprint-type indicators

The assessment of resource use efficiency, which takes into account the global pressure on the environment associated with consumption through footprint-type indicators, was carried out by scientists such as Zhuo L., Liu Y., Yang H., Hoekstra A.Y., Cao X., Wang M., Marston L., Konar M., Mekonnen M.M., Schyns J.F., Booij M.J., Savenije H.G., Gerbens-Leenes W., Vaca-Jiménez S., Vanham D., Aldaya M.M., Garrido A., Llamas R., Hubacek K., Shan Y., Bolton L., Andrew R.M., Peters G.P., Bringezu S., O'Brien M., Schütz H., Bruckner M., Giljum S., Lutz C., Wiebe K.S., Chapagain A.K., Orr S., Chen Z.-M., Daniels P.L., Lenzen M., Kenway S.J., Dietzenbacher E., Los B., Stehrer R., Timmer M., de Vries G., Dittrich M., Bringezu S., Fader M., Gerten D., Heinke J., Lotze-Campen H., Lucht W., Cramer W., Feng K., Chapagain A., Suh S., Pfister S., Giljum S., Herath I., Green S., Horne D., Singh R., McLaren S., Muñoz P., Roca J., Peters G., Davis S., Andrew R., Schmidt J., Weidema B.P., Rees W., Wackernagel M., Weinzettel J., Hertwich E.G., Steen-Olsen K., Galli A., Wood R., Dey C.J. and others.

In recent years, a large number of methodologies, data sets and indicators relating to various categories of footprints, namely material, water, land and carbon footprints, have been presented in scientific literature and international statistics. However, there is still no harmonised methodology for calculating these indicators in the context of assessing resource efficiency. Furthermore, the availability and quality of the data needed to calculate individual footprint indicators vary depending on the methodological approach and the specific category of resource use.

In 2011, the Resource Efficiency Roadmap for Europe introduced a set of resource efficiency indicators that take into account global environmental pressures related to consumption (i.e. footprint-type indicators).

The main indicators for creating a scoreboard on current resource use can be distinguished as follows:

1. Domestic material consumption (DMC) – Raw material consumption (RMC) – requires updating and improvement.
2. Total material consumption (TMC) – still in the methodological development stage.
3. Artificial land or built-up area (km²) – indirect land use/virtual land for agricultural and forestry products (km²) – under development.

4. Water use index (WEI, %) – available water volume, with limitations regarding data completeness and regional/temporal resolution (river basin/interannual variability).
5. Water footprint – needs updating and improvement; virtual water – developed.
6. Greenhouse gas emissions (t) – available.
7. Carbon footprint – estimates available in scientific sources.

However, at the global level, there is still no harmonised methodology for calculating these indicators in the context of resource efficiency.

In addition, the availability and quality of data for calculating various footprint indicators vary depending on methodological approaches. This means that using different methods and underlying data sets to address the same problem can lead to different results. For example, a study comparing differences in countries' total water footprints calculated using different methodologies and data sets found that water footprint values can vary by up to 48%, with even greater differences between economic sectors (Feng), [130]. This poses a challenge for the use of these indicators in policy-making, where reliability, transparency and reproducibility of data and indicators are essential requirements.

It should be emphasised that all indicators can be calculated at the level of products, businesses, households and individuals (micro level).

The term 'footprint' was first introduced by Mathis Wackernagel and William Rees in the early 1990s [131], when the ecological footprint indicator was first proposed to quantify the bioproductive area needed to support a society's resource consumption and waste assimilation at the global, regional or national level, typically using global average productivity factors. This framework was later refined by incorporating local productivity factors to quantify and localise ecological footprints in trade flows [132, 133].

The ecological footprint is a composite indicator that illustrates the total amount of biologically productive land and water needed for an individual, population or activity to produce all the resources consumed and absorb all the waste produced [134]. The ecological footprint is usually consumption-based, which means that it includes all biologically productive areas worldwide needed to satisfy consumption in a given country – including those involved in international trade.

The ecological footprint takes into account demand (expressed as the area needed to satisfy that demand) and regeneration (*known as biocapacity*). It thus combines different types of demand that compete for biocapacity: land for the production of biological resources (crops, fibres, wood), land for waste absorption (e.g. forests absorbing CO₂ emissions), land for urban infrastructure. In contrast, the land footprint only takes into account direct land use and does

not include the carbon footprint. Both the ecological footprint and biocapacity are expressed in global hectares (hectares adjusted for biological productivity per hectare).

Since its introduction, the concept of a ‘footprint’ has been used in many other environmental accounting concepts. For example, in the field of carbon accounting, several studies from the 1990s quantified the potential extent of carbon flows between countries and showed that this could undermine global climate policy through ‘carbon leakage’ – a situation where reducing emissions in one area leads to increased emissions elsewhere [135]. Such approaches to calculating greenhouse gas emissions have also stimulated debate about the responsibility of producers and consumers. From the perspective of consumer responsibility (i.e. carbon footprint), all global emissions are attributed to a country’s final consumption, while from the perspective of producer responsibility, greenhouse gas emissions produced within a country’s production system are taken into account. The difference between these perspectives corresponds to the difference between a country’s exports and imports of virtual greenhouse gas emissions [136].

Recently, the term ‘footprint’ has also been used in relation to indicators of water, land and material consumption and the overall environmental impact of products.

The conceptual overview of the calculation of resource use indicators distinguishes between three perspectives.

The territorial (production) perspective analyses resource use within a country’s geographical boundaries, including resources needed to produce goods for domestic final consumption and exports.

The partial consumption perspective additionally takes into account direct imports into the domestic economy and deducts direct exports. However, it does not provide a complete picture of a country’s resource use in relation to consumption, as it does not include indirect resources contained in imported goods and services and includes domestic resources used to produce exports.

The consumption perspective across the entire supply chain (carbon footprint perspective) includes domestic production for final domestic consumption, all direct and indirect resources contained in imports for domestic consumption. Resource use related to exports is excluded, as this resource use is attributed to the final consumption of another country. Consumption-based indicators can therefore be aggregated across countries to obtain the total carbon footprint of a region (e.g. the EU).

Based on the above information, the following definitions can be formulated for the four footprint indicators.

The material footprint reflects the total amount of materials globally extracted and used throughout the entire life cycle of a product and is attributed to the final consumption of a country. In this sense, the material footprint is the modern equivalent of the earlier concept of ‘ecological backpacks’ [137, 138], which also refers to the material requirements of products during their life cycle. The material footprint can focus either on the extraction of raw materials used (reflected by the *raw material consumption* indicator, RMC) or on material consumption (total material consumption, TMC). Thanks to methodological recommendations from EUROSTAT [139] and the OECD [140], approaches to calculating the material footprint are now widely used at the international level.

The water footprint represents the total volume of fresh water that is directly or indirectly required to produce the goods and services that satisfy a country’s final consumption.

The land footprint estimates the domestic and foreign land area that is directly or indirectly needed to satisfy final domestic consumption. It is important to note that land footprint approaches differ from ecological footprint approaches in that they do not take into account differences in biological productivity when weighting land areas. Unlike the material footprint, there is still no harmonised definition of the land footprint. Due to data limitations, land footprint studies are still mainly used in the agricultural and forestry sectors. The land footprint is expressed in hectares or square metres.

The carbon footprint is one of the most widely used footprint indicators worldwide. It measures the total greenhouse gas emissions that are directly or indirectly caused by economic activities or contained in the life cycles of goods consumed in a given country [141]. Three main standards for carbon footprints have already been published: PAS 2050 [142]; the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) *standard for life cycle accounting and reporting* [143]; and the ISO 14067 standard on the carbon footprint of products [144].

There are generally three groups of methodologies for calculating specific types of carbon footprints.

The first group consists of approaches based on various forms of economic input-output analysis that integrate physical data on resource use (materials, water, land) or emissions (greenhouse gases in the case of carbon footprints).

Input-output analysis is a top-down approach, which means that the assessment starts at the macroeconomic (national or global) level, followed by a breakdown by economic sector using input-output tables. These models can be single-region (one country) or multi-region (several countries or regions).

One of the key applications of input-output analysis is the calculation of the total resource requirements per unit of final product. This approach makes it possible to assess not only the direct use of resources in a particular sector, but also all indirect resource flows contained in intermediate products supplied by other sectors.

The input-output approach – particularly in its multiregional form – offers several important advantages over other methodological approaches [145].

The main advantage is that it allows the carbon footprint to be calculated for all products and all economic sectors, as the entire economic system is included in the accounting framework [146]. This allows input-output analysis to avoid the ‘truncation errors’ that are typical of process-based life cycle assessments, where it is not possible to fully capture the complexity of global supply chains and some processes at the beginning of the chain have to be excluded (‘truncated’).

Input-output analysis thus circumvents the problem of system boundary truncation, which is one of its main advantages over ratio-based methods [147].

Input-output models also eliminate the risk of double counting, as supply chains are clearly distinguished in monetary input-output tables. As a result, a resource can only be allocated to final consumption once, as supply and use chains are fully organised [148].

Another important advantage is that input-output accounting is closely linked to standard economic and environmental accounts, ensuring a continuous process of data collection and verification, at least at the national level.

The main limitation of input-output analysis is that most models operate at the level of broad economic sectors and product groups, assuming that each sector produces a homogeneous product. As a result, a single sector may include several different products with very different resource intensities. This limits the degree of disaggregation possible within this approach and may lead to biased results.

Another disadvantage is the considerable time lag in the publication of input-output (IO) tables, particularly those that are harmonised for MRIO models and those with a high level of disaggregation. IO tables are often published with a delay of several years, sometimes as long as 6 to 10 years.

The second group of methodologies consists of factor approaches, which allow the intensity of resource use throughout the supply chain to be estimated by calculating process-based parameters, such as those used in life cycle assessment (LCA) or similar methods. This is a ‘bottom-up’ approach, where calculations start at the level of individual products or product groups.

Factor-based approaches estimate the total resource use (or greenhouse gas emissions) associated with final consumption by multiplying the direct physical consumption of each resource by a coefficient that reflects the intensity of resource use from cradle to grave. These factors thus provide information on the indirect resource inputs contained in the supply chain of a given product or activity [149].

The main advantage of factor-based approaches over IO-based approaches is their high level of detail and transparency. Factor-based approaches are not limited by sector aggregation, which allows for comparisons of footprints at the level of individual products or materials [149]. This method also allows for a clear and intuitive illustration of the composition of footprints for a product or product category [150].

However, one of the main disadvantages is the considerable effort required to calculate consistent coefficients for a large number of products. In addition, resource intensity coefficients are often only available for a limited period of time. As a result, they may not adequately reflect technological changes and may potentially lead to an overestimation of environmental impacts.

Hybrid approaches represent the third main methodological category, combining elements of IO analysis and factor approaches. Hybrid approaches typically divide the total output assessed into two parts – one calculated using IO analysis and the other using resource intensity coefficients. A review of the literature suggests that many researchers consider hybrid approaches to be the most promising direction for future methodological development, as they combine the advantages of both main methodologies.

A key advantage of hybrid approaches is that the use of coefficients helps to compensate for the typical limitations of IO analysis, which is particularly relevant when evaluating products with low production volumes [151, 152]. At the same time, the strengths of IO analysis – in particular its ability to represent complete supply chains – are retained for products with higher production volumes. However, there is still no agreed methodology for the optimal application of hybrid approaches. Each study selects its own set of products to be assessed using coefficients compared to IO methods.

An analysis of the advantages and disadvantages of the main approaches to carbon footprint calculation is presented in Table 5.1.

A particularly attractive feature of hybrid approaches is that they allow the calculation of ecological footprints for all four main resource categories (land, water, carbon and materials) using a single consistent set of environmental and economic data and the same analytical tools. This ensures consistency, comparability and reliability of results.

Table 5.1

Main advantages and disadvantages of the three basic approaches to calculating the ecological footprint

Characteristics	Cost-benefit method	Coefficient approach	Hybrid approach
1	2	3	4
Coverage of entire supply chains	<i>Single-country models:</i> insufficient representation of import supply chains due to the assumption of domestic production technologies. <i>Multiregional models:</i> complete representation of all international supply chains.	Incomplete representation of entire supply chains, particularly for highly processed products, due to the extensive effort required to assess all bottom-up indirect impacts.	Full representation of supply chains, as more complex chains are modelled using input-output analysis, while coefficients are only applied to primary raw materials and basic products.
Geographical specification	<i>Single-country models:</i> no geographical specification due to the assumption of domestic technology <i>Multiregional models:</i> full consideration of varying intensities of resource use in individual countries	The factors often do not reflect the specific situation of a given country and are usually represented as global or regional averages.	As both approaches are combined, the advantages of geographical specification of costs and benefits can be exploited together with country-specific coefficients.
Details on sectors and products	Limited details for environmentally sensitive sectors and product groups have traditionally been one of the main drawbacks of cost-benefit models.	One of the key advantages is that the assessment can be carried out at the level of individual products and raw materials.	The factor-based approach is used in cases where a high level of differentiation at product level is required, which is particularly important in the case of raw materials.
Double counting	This can be completely avoided, as inputs are only allocated to the final product once within a country.	Risk of double counting, as bottom-up supply chains may overlap, especially for higher-volume products.	Double counting is largely excluded because high-volume production is calculated using a cost-benefit approach.
Timeliness	National cost-benefit tables are usually published with a long delay; in the case of multiregional models, the delay is even greater.	Activity data is often available for recent years, but the coefficients used are often outdated and do not reflect the current situation.	Hybrid models have inherited the same limitations as both basic approaches.
Transparency	Transparency is often limited due to the large volume of data and the complexity of supply chains represented by Leontief inversion. Detailed interpretation is therefore difficult.	Coefficient approaches more clearly reflect key resource flows based on production and trade data. This reduces completeness but increases transparency	Hybrid approaches combine elements of both methods and therefore face similar transparency challenges.

As shown in the table above, there is still no perfect method for calculating footprint-type indicators. Each approach has strong advantages, but also clear limitations. However, hybrid approaches have particularly high potential because they combine the strengths of both basic methods. This methodology is already widely used in practice today.

5.2 Analysis of approaches used in global practice to assess virtual land use

In recent decades, trade liberalisation has significantly increased the volume of trade in agricultural products. As land resources are limited in some countries, international trade plays an important role in compensating for land shortages. It is therefore necessary to assess the level of virtual land use embedded in the imports and exports of individual countries, both for primary crops and processed products. Over the past decade, China's crop imports have continued to expand substantially, driven by population demand, income growth, dietary shifts toward animal protein, and structural constraints on domestic land and water resources. By the early 2020s, China had become the world's largest importer of agricultural commodities in virtual land terms, particularly soybeans and oilseed products.

Net virtual land imports associated with China's international agricultural trade have increased severalfold compared with the late 1980s, rising from a net exporter position in the 1980s to well above 30-40 million hectares per year by the early 2020s, depending on methodological assumptions. This reflects both growing import volumes and the high land intensity of feed and oilseed crops.

The structure of virtual land imports has undergone a profound transformation. Whereas cereals dominated virtual land flows in the 1980s and early 1990s, oilseeds-primarily soybeans-have become the overwhelmingly dominant component since the 2000s. By the 2010s and early 2020s, oilseeds consistently accounted for around 80–85% of China's total virtual land imports embodied in crop trade, reflecting the rapid expansion of livestock production and feed demand.

International agricultural trade has continued to play a land-saving role at the global scale. Updated modeling studies extending earlier analyses indicate that China's participation in international crop trade has resulted in net global land savings on the order of 3-5 million hectares annually, as imports tend to originate from regions with higher land productivity. These savings are particularly pronounced for soybeans and feed crops sourced from South and North America.

Economic growth, urbanization, and policy reforms-together with changing dietary preferences-remain the key drivers shaping China's virtual land trade patterns. At the same time, the concentration of virtual land exports in a limited number of countries has raised

concerns related to deforestation, biodiversity loss, and socio-economic pressures in exporting regions.

To ensure more sustainable global land use, both virtual land importers and exporters must increasingly internalize environmental and social externalities within trade and agricultural policies. Recent policy discussions emphasize deforestation-free supply chains, sustainability standards, and diversification of sourcing as critical instruments for mitigating the negative impacts of expanding virtual land trade.

As agricultural land becomes increasingly scarce worldwide due to population growth, changing consumption patterns and urbanisation, agricultural trade will become an increasingly important tool for countries with limited land resources. The rapid growth of agricultural trade has sparked increased interest in studies assessing the resources embodied in commodities and the associated environmental and socio-economic impacts [132, 154].

In 1965, Borgström introduced the concept of ‘fictitious acreage’ to illustrate the ‘invisible’ use of arable land contained in the trade in agricultural products.

The land footprint typically estimates the area of land that is directly or indirectly needed to satisfy consumption – either for a specific product or for total national consumption [155]. It is a powerful tool for illustrating the dependence of local areas (regions or countries) on foreign land contained in imports and exports («virtual land»), [156].

Another definition and use of the land footprint equates it with the ecological footprint without land for carbon sequestration, as carbon sequestration is already included in the carbon footprint indicator [157]. It is also defined as the amount of biologically productive land needed to satisfy consumption [280]. There is currently no internationally agreed definition of the land footprint [155]. It is important to note that approaches to calculating the land footprint differ from those used to calculate the ecological footprint, as they do not apply weighting factors to land areas with different levels of bioproductivity.

Compared to the footprint concept, which combines different resource uses into a single common measure, the term *virtual land* refers specifically to land resources contained in international trade. Würtenberger et al. [156, 157] defined virtual land as the productive land area hidden in imported or exported agricultural goods. The concept of virtual land is therefore used to illustrate the land resources associated with trade flows.

K. Erb used a country-specific yield index to determine the actual land requirement in Austria and showed that Austria was a net importer of arable land between 1926 and 2000 [157, 158]. Kissinger M. and Rees W. quantified the productive land contained in US imports between 1995 and 2005 and found that in an increasingly globalised world, even countries that

are able to meet most of their needs are becoming more dependent on external terrestrial ecosystems and exerting greater pressure on them [159]. Fayder M. calculated the virtual land balance in international trade in agricultural commodities and found that the United States, Canada, Argentina and Australia are net exporters of virtual land, while several Asian and Mediterranean countries are net importers [160].

International trade flows can contribute to global land savings if trade shifts from relatively more efficient to less efficient producers.

Food systems are major drivers of environmental pressures and public health impacts. Most emissions and other harmful impacts come from primary agricultural production. Their root causes, as well as most mitigation options, are spread across the food system, including dietary choices and multiple vulnerabilities throughout the chain from producer to consumer (i.e. the product life cycle). One of the systemic environmental indicators is *the nitrogen footprint (N)*, defined as emissions of reactive nitrogen compounds associated with the consumption of individuals or other economic entities (in terms of nitrogen use during the life cycle).

Sweden's food nitrogen footprint is estimated at 12.1 kg of nitrogen per capita per year: 42% is emitted in Sweden, 38% is emitted abroad during production, 1% during post-consumer waste management and 19% during wastewater treatment [161].

Foods of animal origin account for 81% of the nitrogen footprint of the diet and 70% of total protein intake. Average protein intake exceeds nutritional requirements by approximately 60%, suggesting that at least 35% of nitrogen-related emissions could be reduced by changing dietary habits.

Of the total nitrogen intake in the diet (6.9 kg N per person per year), approximately 22% (1.5 kg N) is lost as food waste. It is estimated that 76% of the nitrogen in food waste is unavoidable (bones and other inedible parts). Preventable food waste accounts for approximately 7% of edible food, which means that in a hypothetical scenario where all preventable waste is eliminated, emissions could be reduced by approximately 7% [161].

Another example is the calculation of the water and land footprint in a river basin. Optimising water and land use at the farm level can lead to an overall water and land footprint for the entire basin that is not consistent with sustainable resource use. The economic efficiency of water and land use can serve as a guide for crop selection decisions at the micro level in the context of sustainable resource management and subsequently influence decisions at the macro level.

For example, in a proposed sericulture project in Malawi, the water and land footprint of raw materials for silk production (mulberry trees grown as feed for silkworms) was assessed within its production chain, and the economic productivity of water and land was calculated. The results showed that farmers may prefer irrigated raw material production for silk over currently cultivated rain-fed staple crops, as irrigated mulberry trees provide a higher economic return per unit of water and land used. However, the water footprint of irrigated mulberry trees is significantly higher, and sericulture would increase pressure on local water resources. The optimal scenario for such a venture involves drip irrigation combined with organic mulching of the soil surface.

In recent decades, trade liberalisation has significantly increased the volume of trade in agricultural products. As land resources in some countries become increasingly limited, international trade plays an increasingly important role in compensating for land shortages. Analyses of virtual land use in China – for both primary crops and processed products – show that as crop imports to China have risen sharply over the past decade, its net virtual land trade embedded in international trade flows has increased from –4.42 million hectares in 1986 to 28.90 million hectares in recent years. Oilseeds have become the dominant category of virtual land imports, accounting for 82.2% of total virtual land imports [124, 161].

Over the past 20 years, the main regions supplying virtual land to China have shifted from predominantly North America to South and North America. International trade can also reduce global demand for land resources: research shows that crop trade in China has contributed to global land savings of approximately 3.27 million hectares per year on average in recent years. To ensure more sustainable global land use, both virtual land importing and exporting countries need to consider the environmental and socio-economic implications of these trade flows when developing their policies.

International trade flows can contribute to global land and water savings if trade is shifted from countries that are relatively more resource-efficient to countries that are less efficient. Research suggests that international trade leads to net water savings at the global level [118, 160]. Significant land savings are also associated with trade in agricultural products. However, it is important to note that such calculations assume that all other conditions remain unchanged. In reality, increased trade and productivity can lower prices and thus increase absolute demand for resources, especially in the case of food products with elastic demand.

With a population of 1.3 billion, China is the world's largest consumer of food. Land scarcity limits Chinese food production and raises growing concerns about domestic food security and the country's impact on global food markets. China has only about 0.08 hectares

of arable land per capita, compared to a global average of 0.20 hectares per capita and 0.53 hectares per capita in the United States [161].

Improvements in grain yields over the past 30 years have helped compensate for China's lack of land and enabled the country to remain largely self-sufficient in grain. However, as a result of rapid economic development, urbanisation and population growth, agricultural land is now competing with other land uses. The government has introduced a number of measures to protect agricultural land.

China has experienced exceptionally rapid economic growth, with average annual GDP growth of around 8% over the last two decades, one of the fastest rates of growth in the world. As incomes have risen, dietary habits have shifted rapidly towards higher meat consumption. As a result, China now needs to produce not only sufficient quantities of grain, but also a growing volume of animal products. This change, combined with a shortage of land, has made China a significant net importer of virtual land, particularly in the form of soy products.

5.3. The concept of the land footprint

The land footprint, or actual land requirement, is a widely accepted method of estimating the total area of domestic and foreign land required to satisfy the final consumption of goods and services in a given country. It is therefore an effective tool for illustrating the dependence of countries or world regions on external land resources, as reflected in imports and exports (also known as 'virtual land'), [162].

When interpreting the land footprint, it is important to bear in mind that differences in biological productivity are not usually taken into account. Land is calculated without weighting the hectares actually used: one hectare of highly productive arable land is considered equal to one hectare of low-productivity terrestrial pasture. The results of land use thus always reflect the actual or real land used in different countries and regions without taking into account differences in productivity, unlike ecological footprint calculations. This transparency of the land footprint method is an advantage, but it does not always provide a complete picture.

For example, if land use per tonne of wheat is ten times higher in one country than in another, then a consumer of wheat from that country is attributed ten times more land. As a result, the actual land requirement per capita in Australia is about five times higher than in the United States – mainly due to the very low productivity of Australian grasslands (extensive grazing) compared to land in the US. When interpreting land footprint results, it is therefore necessary to take into account differences in soil quality and productivity.

In addition, assessing the various impacts on NPS associated with specific land footprints requires identification of the country of origin and its natural conditions. Identical land areas and land uses can have very different impacts on NPS in different countries. For example, 1,000 hectares of pasture used for cattle grazing may have a much greater environmental impact in Brazil than in the United States. In Brazil, pasture is often created by clearing tropical forests, while in the United States, pasture exists naturally as prairie [162, 163]. In addition to land productivity, it is important to consider both potential and actual natural primary production when assessing impacts on LFA.

The land footprint alone provides valuable information, but when combined with other indicators – such as the material, carbon or water footprint – it provides much more information that allows us to identify the actual efficiency of resource use, as well as the trade-offs and synergies between different categories of natural resource use. For example, palm oil generally requires less land per unit of production compared to other vegetable oils (such as rapeseed oil). However, the expansion of oil palm plantations is often associated with high carbon emissions due to wetland drainage or deforestation – impacts that only become apparent when assessing the land footprint together with the associated carbon footprint.

The land footprint (LF) in crop cultivation represents the area of land (ha or m²) needed to produce a unit of crop output (kg). In other words, the land footprint shows how much land a crop needs, either in absolute terms or in comparison with the reference footprint for that crop, in relative terms [163].

The land footprint is the actual amount of land – regardless of where it is located – needed to produce a product or used by an organisation or nation.

The land footprint is a systematic indicator of land resource use based on life cycle thinking. It reflects the amount of land needed to produce a product or used by an organisation or country and is defined as a value inversely proportional to crop yield:

$$LF = \frac{100}{Y} \quad (5.1)$$

Where LF is the land footprint of the crop, m² /kg; yield, c/ha.

The land footprint can be calculated at different levels: micro level (individual business entity), meso level (river basin, administrative unit level) and macro level (country as a whole).

When deciding which crops to grow, farmers are usually guided by economic considerations related to the efficient use of water and soil resources in their activities. However, optimising water and soil use at the farm level (micro level) can lead to an excessive overall water and soil footprint at the river basin level (meso level), undermining the

sustainability of resource use. Micro-level decisions must therefore take into account their impact at the river basin, national and even global levels.

Economic land productivity (ELP, €/m²) reflects the economic value generated per square metre of land used. Micro-level analysis focuses on the efficiency of land use and the productivity of individual farms or other entities, while macro-level analysis assesses the sustainability and fairness of land use in broader systems such as river basins, countries or the world [164].

The total land footprint at the system level captures the combined impact of all components of the system on land resources. At the macro level, it is common to estimate critical thresholds (assimilation capacity) of total pressure on land to avoid disrupting the sustainability of land resources [164-166]. Exceeding these thresholds leads to undesirable consequences. One way to quantify critical land use at the macro level is to determine the maximum sustainable footprint [167].

If farmers rely solely on micro-level factors – such as the availability of local soil resources, soil footprint or economic productivity of soil for selected crops – the overall soil footprint of the wider system may exceed sustainable levels at the macro level. Conversely, general restrictions on land use at the system level are only effective if their implications for local-level practices can be reliably predicted.

When deciding which crops to grow, farmers are guided by economic considerations relating to the efficient use of the water and soil resources involved in their economic activity. However, optimising water and land use at farm level can lead to a significant overall water and land footprint at river basin level, ultimately undermining the sustainability of resource use. It is therefore important to consider the consequences at river basin, national and global level when making decisions at micro level.

To ensure socio-ecological balance in natural and economic systems, it is necessary to apply technologies and processes that are environmentally appropriate, socially necessary and economically justified (Fig. 5.1).

To measure the socio-ecological and economic outputs (footprints, including land footprints) of actual territorial and economic systems (communities) as well as theoretically possible ones (certified territorial and economic systems), it is appropriate to use the following formula:

$$SEE = K_1 \sum \frac{C_{\text{fact.}}}{C_{\text{theor.}}} + K_2 \sum \frac{E_{\text{fact.ec.}}}{E_{\text{theor.ec.}}} + K_3 \sum \frac{E_{\text{fact.eco.}}}{E_{\text{theor.eco.}}} \quad (5.2)$$

where: SEE – total socio-ecological and economic product of territorial and economic systems (communities); $C_{fact.}$, $C_{theor.}$ – actual and theoretical volumes (quantity of products, services) in the social sphere; $E_{fact.ec.}$, $E_{theor.ec.}$ – actual and theoretical volumes (quantity of products, services) in the ecological sphere; $E_{fact.eco.}$, $E_{theor.eco.}$ – actual and theoretical volumes (quantity of products, services) in the economic sphere; K_1 , K_2 , K_3 – weight coefficients of social, ecological and economic products in natural economic systems.

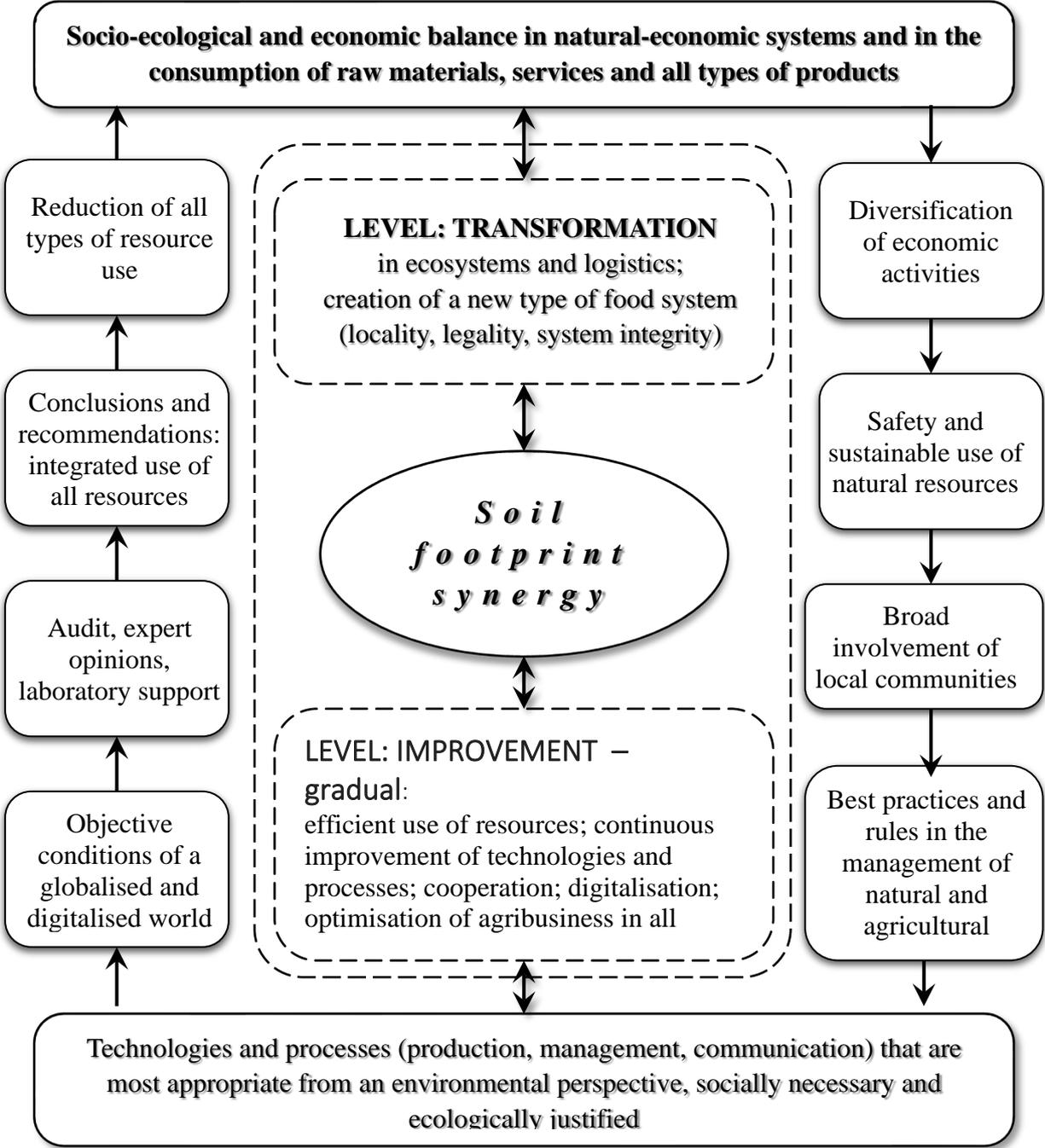


Fig. 5.1. Localisation of economic activities as a tool for reducing all types of carbon footprint

This formula demonstrates a systematic approach to determining land equivalent ratios for comprehensive measurement of agricultural production efficiency on the scale of territorial-economic systems (communities).

The formula is based on the concept of yield differential, i.e. the ratio between the quantity of agricultural products actually produced and the quantity that could potentially be obtained from a single unit of land. This methodology takes into account not only yields but also the provision of all types of services by all land forming a single landscape (a single territory, system – currently the territory of the community). The methodology includes all services relevant to the specific context, taking into account weights determined according to their importance to the relevant stakeholders (social weights). In practice, it may be necessary to adjust these weights across different scales and stakeholder groups, as different groups may assess the importance of the same services differently.

Ukraine's agriculture sector is facing extremely challenging conditions during the state of emergency, despite having significant land potential that is currently being used inefficiently. The Ukrainian government should diversify its existing portfolio of low-value agricultural crops, which currently focuses mainly on staple crops, in order to increase overall productivity, reduce the risk of crop failure, drought and instability and global market conditions, and ultimately increase exports of finished (or semi-finished) products.

5.4. Analysis of Europe's land footprint

Population growth and economic income force us to consider the land footprint (LF) as an important factor in the balanced development of society [155]. More than 75% of the Earth's land area (excluding Greenland and Antarctica) is already used by humans [168]. Land use ranges from very intensive to very extensive. Approximately 1% of land is used for infrastructure and urban areas, about 10-12% is used as arable land, about 26% as forest land, and between 23% [168] and 36% as pasture. Approximately half of the remaining land is unproductive or covered by rock, ice or desert. The other half comprises virgin forests (4.6% of the total area), including tropical forests and other forest ecosystems that show almost no signs of human use [168].

Europe is the continent most dependent on imported land. Nearly 60% of the land needed to meet European demand for agricultural and forestry products is located outside the continent.

As of 2024-2025, the total agricultural land area in the European Union (EU-27) is estimated at approximately 185–186 million hectares. This includes around 117-118 million

hectares of arable land and about 66-67 million hectares of permanent grassland and pastures, reflecting a continued but gradual contraction of agricultural land use.

Over the period 2000-2024, the total utilised agricultural area (UAA) in the EU-27 declined by approximately 7-8 million hectares (around -4%), while arable land decreased by about 3-4 million hectares (-8 to -10%). The reduction has been driven by a combination of factors, including urban expansion, land abandonment in marginal regions, afforestation, environmental conservation measures, and structural changes in agricultural production.

The downward trend has persisted after 2021, albeit at a slower pace, as recent Common Agricultural Policy (CAP) reforms and Green Deal-related instruments have partially stabilised land use through eco-schemes, permanent grassland protection, and land-use conditionality. Nevertheless, long-term structural pressures continue to exert a net negative effect on arable land availability, particularly in Southern and Eastern Member States.

The European Union continues to exhibit a high agricultural land footprint in global terms. Since the early 2010s, the EU has been consistently identified as a net importer of virtual land, reflecting its strong reliance on agricultural imports embodied in global supply chains, particularly for feed crops, oilseeds, and animal products.

By the early 2020s, European countries remained dominant among the world's largest net land importers. Notably, Germany, United Kingdom, Italy, France, Netherlands, and Spain continued to rank among the top global importers of virtual agricultural land. Recent estimates indicate that Germany and the United Kingdom together still account for approximately 70-85 million hectares of net virtual land imports per year, a level comparable to that observed in the previous decade, despite trade reconfigurations following Brexit and supply-chain diversification.

In per capita terms, the EU's agricultural land footprint remains substantially higher than the global average. While the gap has narrowed slightly since the late 2000s, the EU continues to use around 25-30% more agricultural land per capita than the world average. By the early 2020s, average land use associated with consumption in the EU was estimated at approximately 1.1-1.2 hectares per capita, compared to less than 0.4 hectares per capita in highly populous countries such as China and India.

This persistent disparity reflects differences in income levels, dietary patterns—particularly higher consumption of animal-based products and trade specialization. As a result, the EU's land footprint continues to exert significant environmental pressure beyond its borders, reinforcing policy debates on sustainable consumption, deforestation-free supply chains, and the integration of land-use externalities into trade and agricultural policies.

Bringezu et al. suggest that 0.20 ha per person could serve as a medium-term target for sustainable land use by 2030. UNEP has adopted a proposal to move this target to 0.20 ha (1,970 m²) per capita by 2030. The year 2030 was chosen as a practical timeframe for determining the direction and scope of the necessary adjustments [169].

EU measures and programmes to preserve natural production potential (NPP) aim to analyse soil and other footprints. The EU plans to set targets for reducing the overall impact of consumption on NPP throughout the life cycle, in particular to provide a basis for improving resource efficiency aspects, together with greenhouse gas emissions and energy emissions. Indicators and targets for soil, water, materials and carbon footprint will be used to strengthen environmental security.

To achieve the target of 0.20 hectares per person by 2030, the EU would need to reduce its global agricultural land footprint by around 30%. This requires an annual reduction of around 2% until 2030. By comparison, the annual agricultural land footprint has decreased by around 1% over the last decade. In the second half of the 20th century, yield increases effectively compensated for growing demand (e.g. population growth) without the need for additional land. However, most studies predict that yield growth will slow down in the future [170], meaning that additional measures, such as increasing efficiency, reducing waste and reducing consumption, will be necessary to meet the EU's global land footprint reduction target.

In 2024, the EU-27 needed approximately 45 million hectares (Mha) of agricultural land abroad for its imports, of which 42 Mha was arable land. Between 2000 and 2024, the land requirements for imports of oilseeds and wool mostly decreased, while those for imports of cereals, cocoa, coffee, oilseeds and cotton increased. However, these figures fluctuate significantly and some trends are not stable over time.

By the early 2020s, the European Union (EU-27) continued to export substantial volumes of virtual agricultural land, embedded in agri-food exports to global markets. Updated estimates indicate that annual exports of virtual agricultural land amounted to approximately 20-22 million hectares, of which around 17–18 million hectares corresponded to arable land. Compared to the early 2010s, this represents a moderate but persistent upward trend in land embodied in EU exports.

Over the period 2011-2024, the total virtual agricultural land exported by the EU increased by roughly 8-12%, while virtual arable land exports rose by around 10-15%, reflecting both changes in trade volumes and shifts in the composition of exported products. Growth has been particularly pronounced in oilseeds and oilseed-based products, meat, dairy products, and cocoa-based goods, all of which are characterised by relatively high land

intensity. In contrast, the land requirements associated with exported cereals and wool have declined or stagnated, reflecting structural changes in production, productivity gains, and shifting comparative advantages.

As with virtual land imports, year-to-year fluctuations in exported land are substantial, driven by global price volatility, climatic conditions, trade policy adjustments, and geopolitical disruptions. Consequently, not all observed trends are permanent, and medium-term dynamics remain sensitive to both internal EU agricultural policy (notably the CAP and sustainability conditionality) and external market developments.

Overall, while the EU remains a net importer of virtual land, the continued expansion of land embodied in exports underscores the dual role of the EU as both a major global consumer and supplier of land-intensive agricultural products, with important implications for global land use, environmental externalities, and sustainability governance.

These values can also be expected to continue to rise, particularly if Europe increases its use of bioenergy sources such as biofuels and biomass. Every year, Europe imports large quantities of food and other goods from regions around the world.

The land footprint consists of the land within a country that is used for domestic consumption, plus the land contained in imported products such as food and clothing, minus the land used for exported products.

In line with the EU Resource Efficiency Roadmap [171], the European Commission calls for global land use in Europe to be included in the set of indicators for monitoring resource use. Friends of the Earth Europe and the Research Institute for Sustainable Europe also call on Europe to measure its land, water, carbon and material footprints [172].

Research shows that high consumption and strong demand for land-intensive products such as meat, dairy products, wood and other forest products lead to one of the highest land footprints in the world.

The European Union (EU-27) remains a net importer of virtual agricultural land, although the magnitude of net imports has continued to decline in recent years. Net imports prevailed throughout 2000-2024, but their volume decreased further compared with the early 2000s. Relative to the peak years of dependency, net virtual agricultural land imports declined by approximately 8-10% (around 2-3 million hectares), while net imports of virtual arable land decreased by about 2-4% (around 0.5-1 million hectares).

The ratio of net imports to net exports of agricultural land has shown pronounced volatility over time. After rising sharply from around 5-6 in 2000 to a peak of over 20 in the mid-2000s, the ratio declined substantially during the 2010s and early 2020s. By 2023-2024,

the ratio is estimated at around 3-4, broadly comparable to the level observed in 2021 and significantly below historical highs.

This trend indicates a partial rebalancing of the EU-27's position in global agricultural land trade. While the EU remains structurally dependent on imported land embodied in feed crops and oilseeds, its role as an exporter of agricultural and agri-food products to world markets has strengthened in recent years, supported by productivity gains, value-added processing, and sustained external demand.

Overall, the evidence suggests that the EU-27 has not transitioned to net land self-sufficiency but has moved toward a more export-oriented agricultural trade profile, with declining relative dependence on net virtual land imports. This dual position continues to shape the EU's environmental footprint abroad and reinforces the importance of integrating land-use sustainability considerations into trade and agricultural policies.

Land requirements related to net imports are mainly influenced by oilseeds, coffee, cocoa, wool, oilseed meal and cotton. Land requirements related to net exports are mainly related to meat, dairy products and cereals. The results for net land use in EU-27 international trade remain very similar when only arable land is taken into account instead of total agricultural area.

Exports of products made using a country's land resources can have a positive impact on the national economy, but they can also lead to unsustainable land use, loss of biodiversity and disruption of people's livelihoods and control over natural resources. Furthermore, global inequalities in land use are directly reflected in inequalities in health and quality of life. These inequalities cannot be reduced without addressing overconsumption, otherwise global land resources will face unprecedented pressure.

The land footprint is a tool for assessing global land demand that can help determine how Europe and other high-income regions can reduce their global land requirements. Reducing land demand is the only way to ensure fairer global relations in the future and to protect NPS, especially soil resources as a key component of Ukraine's economic security.

As one of the world's largest importers and exporters, the EU food industry also influences the environmental and social footprint of global trade. Improving the sustainability of food systems can strengthen the reputation of companies and products, create value for shareholders, improve working conditions, attract employees and investors, provide a competitive advantage, increase productivity and reduce costs for businesses. The food industry and retailers should lead by example and increase the availability and accessibility of healthy and sustainable food to reduce the overall environmental footprint of the food system. To

support this goal, the EU has introduced an EU Code of Conduct for Responsible Business and Marketing Practices, which is subject to monitoring.

The EU will gradually require food producers to take specific measures relating to food safety, health and sustainability. These include: reformulating food products in line with recommendations for a healthy and sustainable diet; reducing the environmental footprint and energy consumption by improving energy efficiency; adjusting marketing and advertising strategies to take into account the needs of vulnerable groups; ensuring that price promotions do not distort citizens' perception of the value of food; reducing packaging, etc.

The methodology for calculating the national land footprint therefore uses a combination of land use data from the Food and Agriculture Organisation (FAO) and trade data from the Global Trade Analysis Project (GTAP), [173].

This methodology allocates the amount of land used to produce goods to the country where the goods are ultimately consumed. It takes into account the land needed to produce the products (e.g. land used to grow feed for livestock), as well as land located in the country and land contained in imported products. This means that the system can take into account the transfer of production to other regions of the world. The calculations were made for 2004 and 2025, as more recent GTAP data are not yet available. It should be noted that the land footprint can also be calculated for individual products, but this requires a different methodology – one that examines the actual land used to produce the product.

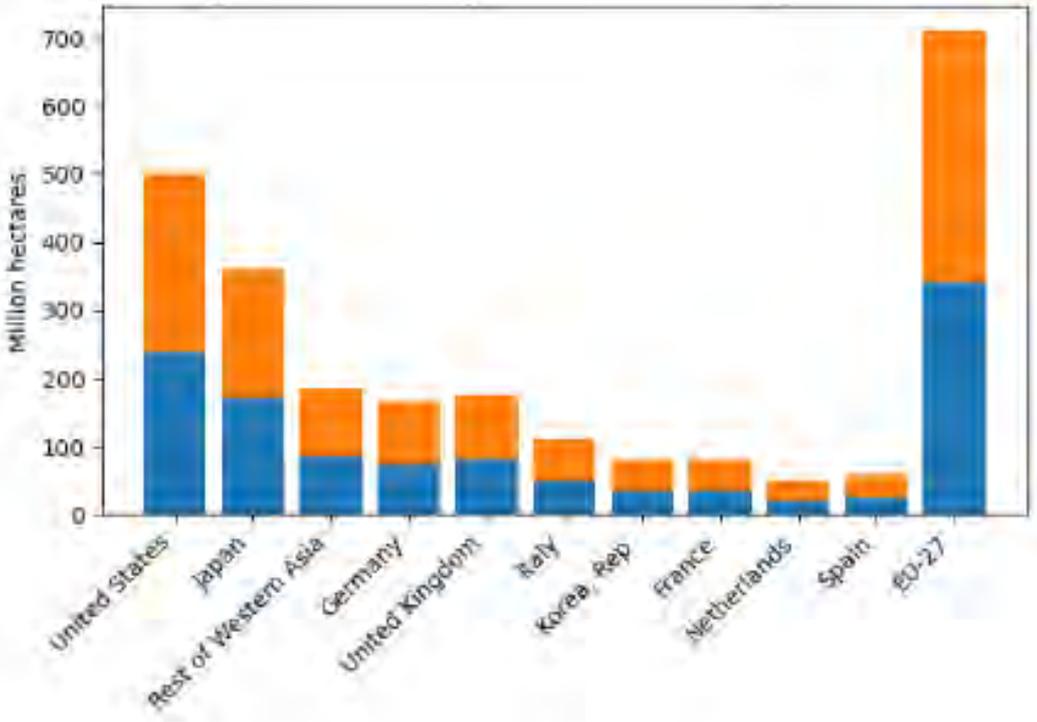


Fig. 5.2. List of the largest land importers, or 15 and 27 EU countries.

The complete results for EU countries are shown in Table 5.2.

Table 5.2

Land area data for EU countries, hectares [173]

Country	Land footprint per capita	Land footprint	Exports (Ex)	Imports (Im)	Net trade (Im-Ex)
1	2	3	4	5	6
Finland	4.1	21,595,964	13,000,534	11,490,170	-1,510,364
Luxembourg	2.9	1,297,590	129,768	1,212,375	1,082,607
Sweden	2.3	20,877,580	13,365,513	10,937,115	-2,428,398
Belgium	2	21,282,602	1,479,248	20,701,984	19,222,736
Ireland	1.9	7,851,785	3,257,432	6,201,568	2,944,136
Denmark	1.9	10,200,070	1,874,925	9,043,071	7,168,146
Netherlands	1.8	28,687,716	1,422,782	27,886,307	26,463,526
Estonia	1.7	2,224,852	1,745,024	1,560,291	-184,734
Latvia	1.6	3,723,592	2,145,098	1,903,766	-241,332
United Kingdom	1.6	95,424,188	4,018,351	80,031,011	76,012,660
Austria	1.5	12,117,236	3,178,661	8,798,188	5,619,526
Lithuania	1.4	4,852,844	1,758,676	2,368,226	609,550
Greece	1.4	15,106,184	1,205,185	9,308,735	8,103,550
Spain	1.3	57,227,363	9,789,442	35,975,199	26,185,757
Slovenia	1.3	2,639,291	486,485	1,792,119	1,305,634
Cyprus	1.3	1,094,786	56,725	982,497	925,772
France	1.3	77,765,086	17,190,515	50,275,788	33,085,273
Germany	1	103,160,633	10,105,290	86,973,091	76,867,800
Portugal	1.2	12,965,529	2,546,774	8,745,153	6,198,379
Italy	1.2	72,028,162	6,433,182	55,217,619	48,784,437
Malta	1	408,358	1,376	399,734	398,358
Bulgaria	0.9	6,947,107	3,592,038	2,172,004	-1,420,033
Romania	0.8	17,556,251	3,710,171	3,869,266	159,095
Hungary	0.8	8,103,818	3,093,059	4,058,612	965,553
Czech Republic	0	7,789,451	2,510,485	4,044,039	1,533,554
Slovakia	0.7	3,538,472	1,270,235	1,628,822	358,587
Poland	0.6	23,760,334	6,389,386	7,986,966	1,597,581
EU-27	1.3	640,226,844	150,756,359	490,563,717	349,807.35
EU-27 additional			36,921,340	374,440,017	337,518.68

Note: Different EU countries include intra-EU trade. The amounts in the bottom rows (EU-27 extra) exclude intra-EU trade and include only trade with countries outside the respective group of countries. Actual land requirements are again not included, as this indicator is not affected by intra-EU trade.

A German study on the land balance modelled the impact of changes in dietary habits and consumption of stimulants (e.g. coffee, wine, etc.) on the land balance in Germany.

It has been found that a shift to a healthier diet with less meat and stimulants could eliminate the need for net soil imports, while a shift to a vegetarian or vegan diet would turn Germany into a net soil exporter.

The International Resource Panel has produced a detailed report on land – «Global Land Use Assessment: Balancing Consumption and Sustainable Resource» – which sets a planetary boundary for arable land and proposes a potentially safe space for cultivation of 0.2 hectares of arable land per person per year. Currently, the EU uses 0.31 hectares of arable land per person per year [170].

Based on the research conducted, the following conclusions can be drawn regarding the land footprint in Europe:

1. High overall demand for land in Europe.

Europe is the region with the second highest total demand for land in the world. The United States consumes the most with 900 million hectares (Mha), followed by Europe with 640 Mha. This means that the EU uses 1.5 times more land than the United States. The EU is followed by China (500 Mha) and the former Soviet Union (330 Mha).

2. Europe's dependence on imported soil.

As illustrated in Figure 5.2, the European countries most dependent on imported land are Germany and the United Kingdom. Each imports around 80 million hectares, of which 10 million hectares come from other EU countries and 70 million hectares come from countries outside the EU.

This is more than three times the size of the United Kingdom and almost twice the size of Germany. In both cases, these imports are mainly due to the high demand for land for feed and meat production.

Europe is the continent most dependent on land imports to meet its high consumption. In 2004, of the EU-27's total land requirement of 640 million hectares, 375 million hectares were imported from outside Europe. In other words, 58% of all land needed for EU consumption came from abroad, mainly from China, the Russian Federation, Brazil and Argentina (Figure 5.3).

3. Global inequality in land use.

The average land consumption per capita in the EU is 1.3 hectares per person, while countries such as China and India use less than 0.4 hectares per person. The average EU citizen uses six times more land than the average Bangladeshi.

4. Trends in land demand.

Europe increased its demand for land per capita between 1997 and 2024. For example, the Netherlands doubled its land consumption in less than ten years. Other countries, such as Finland, Luxembourg and Ireland, also saw a sharp increase in demand for land per capita.

It is worth noting that 2024 preceded a large expansion in biofuel and biomass imports; these flows are likely to significantly increase Europe’s land footprint.

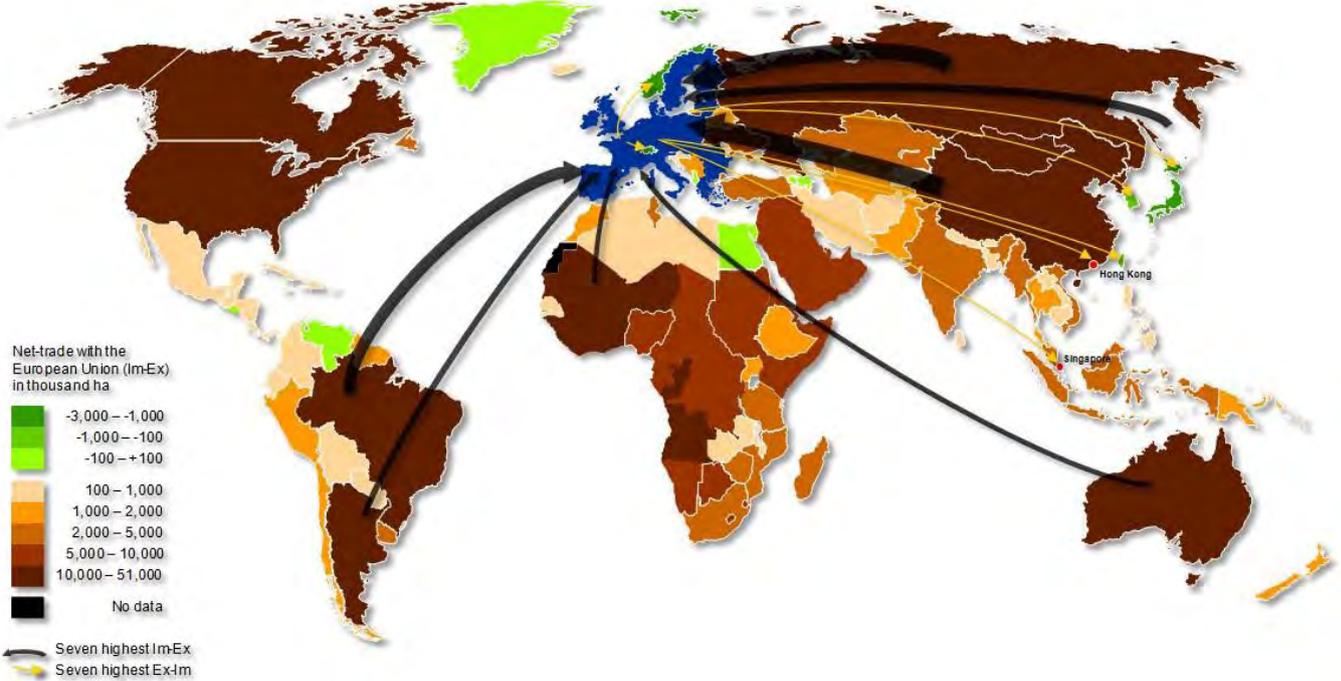


Fig. 5.3. Virtual land trade balance for the EU-27

Friends of the Earth Europe and SERI have provided new evidence showing the extent to which the EU is dependent on both domestic land and indirect land use in other countries. Europe imports huge areas of land and its land use per capita is much higher than in most countries in the world. The world’s population is expected to reach 9 billion by 2050. People around the world will not be able to get their fair share of the planet’s land resources unless Europe significantly reduces its land footprint.

However, global demand for land continues to grow. Rising incomes in large countries such as China and India are contributing to increased land use, for example through growing meat consumption. At the same time, Europe and other regions are moving towards biofuels and biomass, often without sufficiently considering the implications for their land footprint.

Land use in Europe also has significant economic implications. For land-intensive products, this component of production costs is likely to increase, which is already reflected in rising prices for basic foodstuffs. Growing demand for land is leading to land grabbing, which

is likely to affect the cost of importing land into Europe, not to mention the significant economic, social and environmental consequences in the countries affected.

The EU's 7th Environment Action Programme [173] calls for a comprehensive assessment of the land and other footprints, including the development of an action plan to improve resource efficiency (beyond greenhouse gas and energy indicators) and the setting of targets to reduce the overall environmental impacts of consumption throughout the life cycle.

The European Parliament's own-initiative report 'Resource efficiency: towards a circular economy' calls on the European Commission to take action on land and other ecological footprints. In particular, it calls for the development of a system of indicators and a clear overview of resource efficiency indicators – including imports and exports – at EU, Member State and industry level. These indicators should cover the entire life cycle of products and be based on a footprint methodology measuring at least land, water, material and carbon use, and the system should be legally binding.

For economic, social and environmental reasons, the EU must take urgent action to develop a coherent policy for assessing and reducing its land footprint, including:

1. standardising the methodology for accounting for land use and creating the necessary supporting data infrastructure
2. monitoring trends in land use in Europe by requiring Member States to report annually on the amount of land used to meet European consumption.
3. using soil footprint indicators in EU and Member State impact assessments to design policies that reduce the soil footprint and prevent any overall increase in land use in Europe
4. Support businesses and supply chains by providing clear methodologies and guidelines for calculating the land footprint (as well as the water, material and carbon footprints) of their products.
5. Developing new food policies aimed at reducing resource use. Importing virtual land (and other resources) comes with real economic costs, and given that resource prices are likely to rise in the future, it makes economic sense to understand the scale of such land use and work to reduce it.
6. Launching an urgent process to set targets for reducing land use in Europe. The EU should commit to actively promoting policies that reduce its land footprint. This will increase the sustainability of the EU economy and reduce Europe's impact on other regions of the world.

CHAPTER VI. LAND CONSOLIDATION AND ITS ROLE IN EFFECTIVE AGRICULTURAL LAND MANAGEMENT IN THE CONTEXT OF CLIMATE CHANGE AND EUROPEAN INTEGRATION, WITH AN EMPHASIS ON THE INCORPORATION OF GREEN PUBLIC PROCUREMENT INTO LAND CONSOLIDATION IN UKRAINE

This chapter analyses land consolidation as a key mechanism for ensuring the rational use of Ukraine's natural capital. We start from the assumption that land fragmentation and disordered ownership relations hinder the implementation of modern technologies and adaptation to climate change. The chapter integrates the concepts of «land footprint» and «water footprint» into the land consolidation process and proposes a legislative framework for Ukraine in line with EU directives.

6.1. Theoretical basis and definition of land consolidation in the environmental management system and analysis of the current state of soil resource degradation and the need for intervention

The problem of low efficiency in the management of soil and water resources in conditions of intense competition on agricultural markets requires institutional and legislative support. In this context, land consolidation plays an irreplaceable role.

Land consolidation is defined as comprehensive technical, legal and economic measures carried out in a specific area – cadastral area or part thereof – with the aim of organising ownership and usage rights to land and creating conditions for effective and environmentally sustainable agricultural and forestry management, as well as for rural development.

The main objectives of land consolidation, which are directly correlated with the need to preserve Ukraine's natural capital, include:

1. Elimination of fragmentation, which addresses the situation where a single owner owns a large number of small, unrelated plots, making cultivation difficult and increasing costs. In the context of Ukraine, the priority task is to justify diversification of production, which is impossible with high fragmentation.

2. Land consolidation, also known as land consolidation, is a process whereby the owner acquires new, functionally integrated land. This enables the application of precision farming and resource-saving technologies, which is critical as global food demand is set to increase by 70% by 2050.

3. Settlement of ownership relations by resolving unclear entries in the land register, which is essential for the functioning of the land market that is forming in Ukraine.

4. Creating shared facilities and measures, including making land accessible via field roads and implementing anti-erosion and water management measures. These measures are key to mitigating the negative effects of climate change, which is leading to an increase in the frequency and intensity of droughts in Ukraine.

Legislative regulation of land consolidation in Ukraine

The issue of low efficiency in land and water resource management in conditions of intense competition requires a systemic solution, with land consolidation in Ukraine serving as the primary institutional and spatial tool.

Land management in Ukraine is not just a technical measure; it is enshrined in law as a comprehensive set of state-regulated measures aimed at regulating land relations and ensuring its rational use, as specified in detail in the Law of Ukraine on Land Management. This law defines land management as a cross-sectoral set of measures that include not only legal and economic aspects, but also environmental and technical aspects, aimed at:

1. Functional and Environmental Organisation of the Territory – creation of an optimal spatial organisation of agricultural land, which must be in line with the objectives of soil protection, its reclamation and ensuring the ecological stability of the landscape.

2. Technical documentation as a legal basis – production of detailed technical documentation and designs that are binding for registration in the State Land Registry and serve as a legal basis for the implementation of all measures, including erosion control systems and agroforestry elements.

3. Support for the Land Market – in the context of land market reform (from 2021) [174], the key objective is to resolve unclear ownership records and transform fragmented plots of land into functionally coherent ownership units. This is essential for land to enter full market circulation and attract sustainable investment.

In the Ukrainian context, the objectives of precision farming are directly correlated with environmental requirements:

– Land consolidation as a prerequisite for precision farming – land consolidation not only addresses the costs of cultivation, but is also a technical prerequisite for the application of precision farming and resource-saving technologies (water, fertilisers, pesticides). This is critical for reducing anthropogenic pressure on the soil.

– Creating shared facilities as an adaptation measure - Implementing shared facilities (field roads, water management elements, biocorridors) serves as an essential measure for

adapting the landscape to climate change, e.g. increased frequency of droughts and torrential rains.

Land management in Ukraine is ensured by a comprehensive, hierarchically structured network of central and regional institutions that determine where and how green public procurement will be implemented:

Table 6.1

Network of central and regional institutions

Institution	Function and legislative basis	Link to Environmental Management and GPP
State Service of Ukraine for Geodesy, Cartography and Cadastre	(Derzhgeokadastr: Central authority for land management and maintenance of the State Land Cadastre. It manages state-owned land and is the main public procurer for most land management projects.	Key addressee of the GPP: As the main contracting authority, it must transform its tenders to MEAT and LCC criteria. It is responsible for the accuracy of data that forms the basis for environmental planning.
Ministry of Agrarian Policy and Food	(Ministry of Agrarian Policy): Creation of strategic agricultural and land policy. Defines long-term visions for land use.	Strategic Management: Guides the need to introduce environmental technologies and NBS solutions in LC. Cooperation with Derzheokadastr on the implementation of green policies.
Ministry of Environmental Protection and Natural Resources	(Ministry of Environmental Protection): Regulatory and supervisory authority for the protection of biodiversity, water and air.	Control and Approval: Ensures that the environmental part of LC projects complies with Ukrainian legislation and international commitments. Issues permits.
United Territorial Communities	(UTC – United territorial communities): The closest executive body to the land. They approve LC projects at the local level and manage municipal land.	Local Implementation of the EIA: UTCs, as local procurers, must be trained to implement the EIA and monitor the environmental results of field work.
Licensed Entities and Institutes	(Private companies, scientific institutes): Private and state institutions licensed to develop <i>land management</i> projects.	Environmental Qualification: These are primary suppliers. They must demonstrate the ability to design NBS, assess LCC and meet the requirements for environmental certificates (ISO 14001).

Source: Author's own work

Ukrainian land management is therefore a state-controlled, legally binding, spatial mechanism that naturally integrates economic, ownership and environmental objectives. Any land management project involves public procurement of technical works and services. Therefore, the implementation of Green Public Procurement (GPP) into this system is not only compatible but also necessary to fulfil its defined objectives: the transition to environmentally sustainable agriculture, minimising erosion and successfully reconstructing the landscape after the war in accordance with the standards of the European Green Deal. The introduction of GPP transforms LC from a solution to property disputes into a strategic tool for environmental management.

Analysis of the current state of soil resource degradation and the need for intervention

The current use of soil resources in Ukraine, which is known worldwide for its unique layer of black soil, is marked by structural unsustainability. Persistent agricultural practices are leading to widespread and systematic degradation. Almost all economic entities in Ukraine continue to show a trend of soil degradation, which threatens food security not only in the country but also in the global market.

The need for comprehensive land consolidation is therefore not only based on economic reasons (fragmentation), but above all on the urgent need to ensure the environmental sustainability of the soil fund.

The development of various forms of land ownership and management without strict and reliable state environmental and customs controls on imports of hazardous waste, and the lack of an appropriate legislative framework, leads to a consumerist attitude towards land. The use of large quantities of mineral fertilisers, pesticides and other chemicals, together with industrial and radiation pollution, may further complicate the ecological situation in Ukraine, reducing the reproductive capacity of the biosphere and the ecological sustainability of the agricultural landscape. [174].

Land management must respond to the following critical factors identified in the analysis:

1. Erosion and physical degradation of soil

Erosion is the most widespread form of degradation in Ukraine and is reaching alarming proportions. It causes not only the loss of fertile topsoil, but also the deterioration of the physical properties of the soil, reduced water infiltration and the loss of organic matter. Water erosion affects 13.4 million hectares (more than a third) of agricultural land, of which 10.6 million

hectares are arable land. Wind erosion (deflation) affects more than 6 million hectares [175, 176]. The extent of these processes is directly caused by the high level of arable land (54% of total arable land) and the inefficient arrangement of soil blocks, which hinders the implementation of anti-erosion measures. Crop losses on eroded soils are estimated at 20 to 60% compared to non-eroded soils, representing significant economic losses [177]. The northern problem – waterlogging. In the north (Polissia region), the problem of soil waterlogging (hydrogen degradation) persists, with 48.4% of agricultural land in the Polissia zone being moderately to severely acidic, which is exacerbated by erosion and inadequate maintenance of drainage systems [178].

2. Water stress and the impacts of climate change Climate change will increase the average annual temperature in Ukraine by 0.8–1.1 °C by 2040, which will dramatically change the water regime.

Table 6.2

Expected temperature changes and impact on agricultural land in Ukraine

Region of Ukraine	Short-term outlook (2011–2040)	Medium-term outlook (2041–2070)	Long-term outlook (2071–2100)	Impact on land use
West	+1.1 to +1.3 °C	+1.8 to +2.8 °C	+1.9 to +4.5 °C	Need for anti-erosion measures (water erosion, terraces) and surface runoff management.
South	+1.0 to +1.4 °C	+1.8 to +3.1 °C	+2.0 to +4.9 °C	Critical need for irrigation systems, agroforestry systems (windbreaks) and reconstruction of drainage infrastructure.
East	+1.0 to +1.4 °C	+1.8 to +3.0 °C	+1.9 to +4.7 °C	Measures against soil deflation and drying (soil protection technologies) and prevention of further salinisation.
North	+1.0 to +1.3 °C	+1.8 to +2.8 °C	+1.9 to +4.5 °C	Restoration and maintenance of drainage systems (against waterlogging); Water retention in the landscape and erosion control.

Source: Prepared by the author based on climate models for the regions of Ukraine and Kyiv.

More critical are changes in the precipitation regime, leading to more extreme weather events (more frequent droughts and more intense torrential rains). Increased aridity and erosion: Climate models predict a northward shift in climate zones, meaning that southern and central Ukraine will face more frequent and intense heat waves and prolonged periods of drought. Modelling of the impacts of climate change on the Polissia and Lesostep regions (north and north-east) even predicts an increase in soil loss due to water erosion in up to 65% of the areas studied by 2060, mainly as a result of changes in the intensity and distribution of precipitation [179]. Desertification forecasts: If the current trend continues, the forecasts are dire: by 2050, 3 million hectares of arable land in the southern regions of Ukraine may become unsuitable for commercial production due to desertification and a decline in organic matter. Land management must therefore integrate water management elements to retain water in the landscape, as well as restore drainage infrastructure in the north.

Legislative framework for land consolidation in Ukraine

The new legislative environment, created primarily by the adoption of Law № 2178-10 (of 31 March 2020) amending the Land Code and other legal acts, is key to the implementation of comprehensive land consolidation. This law, which lifted the long-standing moratorium on the sale of agricultural land (effective from 1 July 2021), is a prerequisite for a functioning land market and has also made available tools to address the persistent fragmentation of the land fund.

The key aspects of the legal framework affecting land consolidation and the fight against degradation are:

1. Fragmentation – the new legislation implements tools to prevent further fragmentation of land, in particular through the introduction of a right of first refusal for existing tenants. This should strengthen the economic sustainability of farming entities and facilitate subsequent consolidation projects, which are necessary for the meaningful application of anti-erosion measures (e.g. on large contiguous blocks).

2. Decentralisation of administration – a key change is the transfer of responsibility for state-owned land outside settlements and for land use management to local authorities (hromady). This step is critical because land consolidation is primarily planned and managed at the local level. Local authorities are thus the main entities responsible for developing projects and implementing environmental measures within their territories.

3. Regulation of land consolidation – while Law № 2178-10 laid the foundation for the market, the practical implementation of land consolidation requires a specific Land

Consolidation Law. This regulates in detail procedures such as the establishment of local land consolidation commissions, the management of owner consent (international recommendations refer to the need to achieve, for example, 75% consent for a project to be binding) and fair compensation mechanisms.

4. Integration of environmental objectives - in order to meet sustainability objectives, the legal framework must ensure that land consolidation projects are multidisciplinary and integrate not only economic consolidation but also mandatory elements for soil protection, water management (water retention, drainage systems) and the creation of a territorial system of ecological stability (e.g. anti-erosion windbreaks). Legislation must actively promote the function of land as a natural resource and not just as a commodity.

The table and analysis show a clear regional differentiation of needs to which land consolidation must respond: Southern and Eastern regions (Steppes): The priority is to address water deficit and deflation. This requires the construction of irrigation infrastructure and the implementation of extensive agroforestry systems (restoration and new establishment of windbreaks) as part of land consolidation. Western regions (Carpathian region, slopes): The priority is protection against water erosion due to heavy rainfall. This requires technical anti-erosion measures and the reorganisation of plots so that contour farming and the creation of vegetation strips can be implemented. Northern regions (Polissia, Lesostep): The priority is to restore and maintain drainage systems to eliminate waterlogging and hydrogen degradation of the soil, as well as measures for local water retention to mitigate the negative effects of summer droughts and torrential rainfall.

Land consolidation thus plays a key role in the transition from unsustainable land management to models that are resilient to climate change and meet environmental standards.

Determining the economic efficiency (EE) of land consolidation is key to justifying public and private investment. EE is assessed not only in terms of costs and savings in land management, but also in terms of environmental and social benefits, which are crucial in the context of land degradation and climate change. The methodology for calculating EE is based on the principle of cost-benefit analysis (CBA).

Basic formula for measuring efficiency

Economic efficiency is most often expressed in terms of Net Present Value (NPV), which compares the sum of all discounted benefits (B) with the sum of all discounted costs (C) over the planned time horizon of the project (T), [180].

$$NPV = \sum_{t=0}^T \frac{(B_t - C_t)}{(1 + r)^t} \quad (6.1)$$

Where:

- NPV – Net Present Value (in monetary units, e.g. in hryvnias or EUR).
- B_t – Annual benefits (advantages) of the project in year t.
- C_t – Annual costs of the project in year t.
- r – Discount rate (expresses the preference for the present value of money over the future value and reflects risks, e.g. 5-7%).
- T – Economic life (horizon) of the project (usually 20–30 years).

If $NPV > 0$, the project is economically efficient. An alternative indicator is the benefit-cost ratio (B/C ratio), where a B/C ratio > 1 means that the project is efficient.

Quantification of benefits (B_t)

The benefits of land consolidation are divided into direct (economic) and indirect (environmental and social).

$$B_t = B_{econ, t} + B_{env, t} + B_{soc, t} \quad (6.2)$$

Table 6.3

Benefits of land consolidation

Benefit category	Component and calculation methodology	Formula for component
1	2	3
Direct economic (B_{econ})	1. Operating cost savings (improved shape and accessibility of parcels) – Fuel and labour savings due to reduction in unproductive travel. 2. Increased yields (optimisation of water management and erosion control) – Increased yields on consolidated and protected land. 3. Reduction of losses (Removal of obstacles, better drainage, less damage to equipment)	$\Delta C_{operating} = (H_{poriginal} - H_{new}) \times C_{hod}$ $\Delta Z_{harvest} = \Delta Y \times A \times P_{crops}$ ΔS_{losses}

continuation of the table 6.3

1	2	3
Indirect environmental (B_{env})	<p>4. Cost savings from mitigating degradation (anti-erosion measures) – Quantification of the value of prevented soil and organic matter loss (e.g. based on replacement costs).</p> <p>5. Water management benefits (water retention in the landscape) – Reduction of flood damage and increased water availability during droughts (valued through the costs of replacement supplies).</p>	$B_{erosion} = \Delta M_{soil} \times C_{regeneration}$ $B_{water} = \text{Reduction in damage}_{pwater} \times \text{Value}_{retainedwater}$
Indirect social (B_{soc})	6. Value of new infrastructure – Benefits of constructing field roads and drainage systems for the local community (valued through construction costs).	$B_{infra} = C_{new\ road} \times f_{soc}$

Source: Ministry of Agriculture and Rural Development of the Slovak Republic. Methodological guidelines/Handbook for the preparation of cost-benefit analysis (CBA) for land consolidation projects/Rural Development Programme. URL: <https://www.mpsr.sk/>

Where H is time (hours) per hectare, C_{hour} is the hourly cost of mechanisation, ΔY is the change in yield, A is the area, P_{crops} is the market price, ΔM_{soil} is the volume of soil saved, and $C_{regeneration}$ is the cost of regeneration.

Quantification of Costs (C_t)

Project costs include all one-off investments (at $t=0$) and annual maintenance costs.

[181]

$$C_t = C_{preparation, t} + C_{implementation, t} + C_{maintenance, t} \quad (6.3)$$

Table 6.4

Investments

Cost category	Components	Formula for component
Preparation costs ($C_{príprava}$)	Surveying, legal services, project documentation (all at $t=0$).	$C_{príprava} = \Sigma (N_{geodetic} + N_{design} + N_{legal})$
Implementation costs ($C_{implementation}$)	Marking out, moving boundaries, construction of new field roads, water management structures (drainage, irrigation), agroforestry systems (windbreaks).	$C_{príprava} = \Sigma (N_{geodetic} + N_{design} + N_{legal})$
Maintenance costs ($C_{maintenance}$)	Annual costs of maintaining new infrastructure and erosion control measures (cleaning, repairs, in $t=1$ to T).	$C_{maintenance} = C_{annual} \times A_{project}$

Source: Ministry of Agriculture and Rural Development of the Slovak Republic (MPRV SR). (Current year of publication). Methodological guidelines/Handbook for the preparation of cost-benefit analysis (CBA) for land consolidation projects.

Key input parameters for Ukrainian projects

In the context of land degradation (Chapter 6.2.), projects must specifically take into account:

a) Input parameter – the value of prevented erosion loss must quantify the value of the loss of 1 tonne of black soil, which is a highly valued asset in Ukraine, in order to fully reflect the environmental benefits.

b) Given the high instability and risk in Ukraine (including the risk of war), the discount rate (r) should be set higher (e.g. 7-10%) to reflect the expected return in a shorter time frame.

c) When calculating the benefits (B) of climate change externalities, the resilience premium generated by the project should be included (e.g. the value of an irrigation system in a drought year).

This methodology enables a comprehensive and transparent assessment of land consolidation projects in Ukraine, with an emphasis on their long-term sustainability and regional priorities (combating erosion in the west, drought in the south, and waterlogging in the north).

6.2. Land and water footprint in the land consolidation process

Modern land-use planning is increasingly confronted with the dual challenge of ensuring food security while remaining within the ecological limits of land and freshwater systems. Classical land consolidation approaches, which have traditionally focused on cadastral simplification, parcel enlargement and road accessibility, are no longer sufficient to address these systemic pressures. Contemporary sustainability science requires that spatial land arrangements be evaluated not only in geometric or economic terms, but in terms of their biophysical efficiency, i.e. the amount of land and water required to generate a unit of agricultural output. In this context, the land footprint and the water footprint have emerged as key quantitative indicators for embedding environmental limits into land-use design [136].

The land footprint is defined as the area of land required to produce one unit of agricultural output, usually expressed in hectares per tonne of crop (ha/t). This formulation is mathematically equivalent to the inverse of yield, since yield itself is defined as tonnes per hectare (t/ha). Accordingly, the land footprint can be written as $LF = 1/Y$, where Y is crop yield [152]. This relationship gives the land footprint a powerful interpretative meaning: it directly reflects how much pressure agricultural production places on terrestrial ecosystems. A high

land footprint indicates extensive land use and greater encroachment on natural habitats, whereas a low land footprint reflects more efficient land use and lower ecological stress.

This identity is not just a mathematical convenience; it is conceptually consistent with footprint thinking, where “resource efficiency means a small footprint per unit of product” [156]. The critical implication for land consolidation is straightforward: if consolidation improves *effective* yields (by reducing operational losses, enabling better mechanisation, improving access, and making field operations more precise), it reduces LF even if total cropped area stays constant. Put differently, the same production target can be met with less land, producing a land-saving effect. If baseline yield is Y_0 and the redesigned configuration increases yield to $Y_1=Y_0(1+g)$, then:

$$LF_1 = \frac{1}{Y_1} = \frac{1}{Y_0(1+g)} = \frac{LF_0}{1+g}, \quad (6.4)$$

so a 20% yield gain ($g=0.20$) reduces land footprint per tonne by $1/1.2 \approx 16.7\%$. If the policy target is to keep output fixed at Q , the “freed” land can be expressed as:

$$\Delta A = Q\left(\frac{1}{Y_0} - \frac{1}{Y_1}\right) \quad (6.5)$$

This is where consolidation becomes ecologically strategic: land released from production pressure can be reassigned to ecosystem services (e.g., habitat corridors/biocentres, riparian buffers, carbon-rich grasslands, or water retention areas), thereby turning a cadastral intervention into a nature-positive spatial redesign aligned with biodiversity objectives that stress “giving nature the space it needs” (European Commission, 2020).

Land consolidation fundamentally alters this relationship by influencing the spatial determinants of yield. Numerous empirical studies show that fragmented, irregular and poorly accessible land parcels reduce effective productivity due to edge losses, inefficient machinery use, longer transport distances and suboptimal water management [187]. When land consolidation improves parcel shape, road access and irrigation layouts, yields typically increase even if input levels remain constant. Reported yield gains of 10–30% following consolidation are common in Central and Eastern Europe [187]. Because the land footprint is inversely proportional to yield, these increases translate directly into a reduction in land footprint, meaning that the same amount of food can be produced using substantially less land.

This reduction generates what land-use science refers to as a land-saving effect. Intensification driven by improved spatial organisation allows agricultural output to grow while the total cultivated area declines or stabilises, releasing land for alternative uses [144]. Freed land can then be allocated to ecosystem services, including biodiversity conservation, carbon sequestration, flood regulation and landscape connectivity. Weinzettel et al. [144] demonstrate that yield-driven reductions in land footprint are one of the most effective mechanisms for reducing global deforestation pressure without undermining food production.

The water footprint extends this logic to freshwater systems by measuring the volume of water consumed and polluted per unit of agricultural output. It distinguishes between green water (rainwater stored in soil), blue water (surface and groundwater used for irrigation) and grey water (the volume required to assimilate pollution), [101]. Land arrangement has a strong influence on all three components. Fragmented plots lead to inefficient irrigation layouts, higher conveyance losses, increased pumping energy and uneven water distribution. Conversely, consolidated and hydrologically optimised field structures allow irrigation systems, drainage networks and soil management practices to be designed more efficiently, reducing both water consumption and nutrient leaching [187, 189].

Once land and water footprints are treated as core metrics, footprint-based land consolidation becomes a genuine optimisation problem rather than a technical boundary adjustment. Let x denote a candidate land arrangement (parcel geometry, road/access network, drainage and irrigation layout, ecological set-asides). A planner can formulate an ex ante decision model that selects x to meet a production target while minimising combined pressures:

$$\min_x [\omega_L \cdot LF(x) + \omega_W \cdot WF_{total}(x)] \text{ s.t. } Q(x) \geq Q \quad (6.6)$$

legal/cadastral constraints, social constraints.

This is exactly the kind of “combining footprints” and making trade-offs explicit that footprint science highlights as necessary, because reducing one footprint can increase another if policy design is not careful [152]. In practice, the modelling workflow is: (i) simulate yields and water use for multiple spatial configurations; (ii) compute LF and WF per unit output; (iii) quantify the land-saving potential ΔA ; and (iv) test where released land can deliver the highest marginal ecosystem benefit (biodiversity connectivity, flood mitigation, carbon storage). In this sense, footprint indicators are not merely “reporting tools” but design variables that allow land-use change to be evaluated against biophysical thresholds before physical implementation.

This approach also fits directly into the EU policy logic that increasingly frames food systems through environmental performance. The European Green Deal calls for deeply transformative, cross-sector policies and explicitly flags the need to manage trade-offs between economic, environmental and social objectives [85]. The Farm to Fork Strategy stresses reducing the environmental and climate footprint of the food system and links resilience to climate change and biodiversity loss [95]. The EU Biodiversity Strategy for 2030 frames recovery and resilience through protecting and restoring ecosystems and maintaining “sustainable supply chains and consumption patterns that do not exceed planetary boundaries”. A footprint-based consolidation framework provides an operational bridge between these policy goals and concrete spatial decisions: success can be expressed not only as “hectares consolidated” but as hectares saved per tonne, m³ saved per tonne, and pollution assimilation pressure reduced—all measurable at the design stage.

Finally, the strategic relevance for Ukraine is twofold: reconstruction and European integration. The EU has officially opened accession negotiations with Ukraine, which raises the value of tools that can demonstrate (with quantitative indicators) that agricultural modernisation and land reform can proceed without locking in environmental degradation. At the same time, post-war recovery processes explicitly include a “European dimension” connected to EU accession and related reforms. In such conditions, land arrangement that is footprint-optimised offers an evidence-based narrative: it frames consolidation as a pathway to maintain production and competitiveness while actively reducing land and water pressures, and it creates a transparent metric basis for allocating released land to restoration priorities (biocentres, buffers, water retention), which is exactly the kind of integrated, measurable sustainability logic that contemporary EU policy expects.

From a sustainability perspective, the integration of land and water footprints into land consolidation design transforms spatial planning into a resource-efficiency optimisation problem. Rather than merely maximising output per hectare, planners can minimise land and water use per tonne of crop. This is directly aligned with the concept of planetary boundaries, which identifies land-system change and freshwater use as two of the most critical global sustainability thresholds.

Crucially, land and water footprints can be applied ex-ante, before any physical reallocation of land takes place. By modelling alternative parcel layouts and infrastructure designs, planners can calculate expected yields, land footprints and water footprints for each scenario. This allows the selection of land arrangements that achieve the lowest ecological

pressure for a given level of production, moving land-use planning from reactive environmental mitigation to proactive sustainability design [152].

In this way, land consolidation that increases yields through improved plot shape and accessibility does not merely enhance farm efficiency. It actively reduces the land footprint, frees land for biocentres and ecological corridors, lowers the water footprint of agricultural production and contributes to long-term ecological stability. The integration of footprint metrics thus enables land-use planning to deliver the core objective of sustainable development: more food, less land, less water and more nature.

6.3. Comparative analysis of Ukraine vs. Poland and implications for land consolidation

A comparison with Poland, a country with similar natural conditions but a different agricultural structure and a more advanced level of implementation of EU instruments, is key to setting up processes in Ukraine.

Table 6.5

Comparison of virtual water and land use (Ukraine vs. Poland)

Indicator	Poland	Ukraine	Interpretation for land consolidation
Virtual water exports (agricultural products)	3,946.3 million m ³ /year	15,289.2 million m ³ /year	Ukraine exports water on a massive scale in the form of raw materials, which requires more efficient water management in the context of land consolidation.
Land footprint per capita	0.6 ha	Higher (estimate)	Ukraine has more extensive land use, and land management must increase intensity while preserving ecology.
Net trade in virtual water (green water)	+5,701.4 million m ³	-12,658 million m ³	Ukraine has a negative balance, which threatens water security.

Source: [180]

The Ukraine-Poland comparison based on virtual-water and land-pressure indicators should be presented not as a descriptive table commentary, but as an evidence-based statement about different national profiles of resource vulnerability that require different land-consolidation priorities. According to the values in your table, Ukraine exports 15,289.2 million m³/year of virtual water embedded in agricultural products, compared with 3,946.3 million m³/year for Poland. This difference is not merely quantitative: it indicates that Ukraine operates as a substantially larger exporter of natural water capital through raw-material commodity flows. The interpretation is consistent with comparative assessments of water footprint and virtual-water trade that characterise Ukraine as a net exporter of virtual water and Poland as a net importer, i.e., the countries occupy opposite positions in the regional resource exchange. In applied land-policy terms, this means that Poland can treat land consolidation primarily as an instrument for improving farm structure and territorial infrastructure (roads, access, field layout, alignment with drainage), whereas Ukraine risks turning consolidation into a mechanism that accelerates exports of water-intensive raw materials unless the project design explicitly incorporates compensatory water-regulation capacity at landscape scale. Polish consolidation practice is frequently embedded in a broader territorial-development logic in which the outcome is not only improved parcel geometry but also functional infrastructure (particularly road systems and, in many cases, links with melioration/drainage arrangements), offering a useful benchmark of “consolidation plus territorial development” rather than consolidation as an isolated cadastral operation.

The second difference is even more directly relevant for planning: your table reports net trade in green virtual water as positive for Poland (+5,701.4 million m³) and sharply negative for Ukraine (−12,658 million m³). In a monograph-style interpretation, this should be read as evidence of different levels of “hydrological buffering” and different capacities to compensate water risks through trade structure. For Ukraine, a strongly negative green-water balance implies that the water-retention dimension cannot be treated as an optional environmental add-on. Instead, it must become a mandatory core of land-consolidation projects: wetlands restoration where hydrologically feasible, floodplain space, polder-type solutions in appropriate lowlands, controlled drainage, runoff-retention strips, and other small-scale or landscape retention measures should be embedded as spatial constraints and as an infrastructure package that restores water-regulation functions. This need is strengthened by longer-horizon analyses of Ukrainian crop production and trade that document a shift toward water-intensive crops and emphasise the necessity of more sustainable water management in the agricultural sector. Consequently, consolidation that increases operational efficiency in Ukraine should

simultaneously reduce the water intensity of the export basket (m^3 per tonne and, ideally, m^3 per unit of export value); otherwise, economic gains may be structurally “paid for” by a rising dependence on water as a limiting factor.

The third difference concerns land footprint. Your table provides a land footprint per capita of 0.6 ha for Poland and indicates a higher (estimated) value for Ukraine. The correct monographic conclusion is not to frame this as “intensification versus ecology,” but to specify a requirement for Ukraine: increase land-use performance primarily through spatially enabled sustainable intensification – reducing fragmentation, improving accessibility, consolidating field blocks, and upgrading territorial engineering – so that land pressure per unit output declines while part of the land-saving potential can be reallocated to ecological functions. Here, Poland is again useful as an organisational reference: policy-oriented consolidation materials for Poland emphasise that consolidation outcomes include not only fewer parcels and better shapes, but also road infrastructure and coherent territorial functionality. For Ukraine, the benchmark must be expanded to “post-consolidation development plus water regulation,” because Ukraine’s trade position indicates a structural role as a large net exporter of virtual water.

These contrasts lead to clear design implications for land consolidation. First, in Ukraine, consolidation projects should be approved only if a measurable water package is included: retention-area targets, buffer-strip length/area, controlled-drainage coverage, and indicators showing reduced runoff and diffuse pollution risks at block or catchment scale. Second, Ukraine should institutionalise a multifunctional objective and robust governance: FAO recommendations for Ukraine’s land-consolidation policy design emphasise voluntary uptake at the start, multifunctionality, integration with broader local-development needs, and clear procedures and safeguards for legitimate tenure rights. Third, Poland provides a procedural warning: recent research on Polish consolidation points to substantial implementation delays associated with administrative complexity and appeal mechanisms, generating multi-year project cycles and reducing spatial-management efficiency. For Ukraine – where the scale of potential restructuring is larger – fast dispute-resolution mechanisms and procedural “filters” must be designed from the outset; otherwise consolidation will not scale to the level required by its water-security significance.

In monograph terms, the Ukraine-Poland comparison derived from your indicators supports one central conclusion. Poland can evaluate land consolidation mainly as a farm-structure and infrastructure instrument, provided procedural efficiency is maintained. Ukraine, however, must evaluate land consolidation as an instrument of resource security, where the core

task is not only to consolidate parcels but also to retain water in the landscape, reduce the water intensity of an export-oriented agricultural model, and embed water-regulation measures into the spatial blueprint of each project. This conclusion is consistent with comparative water-footprint and virtual-water trade assessments for the two countries, as well as with recent empirical work highlighting the water intensity of Ukraine's agricultural exports and the need for more sustainable water management.

For **Ukraine**, land consolidation should be institutionalised as a water-aware territorial policy rather than a narrowly cadastral exercise. Given the scale of virtual-water export embedded in agricultural commodities and the negative balance in green virtual-water trade in your comparative indicators, every consolidation project should include a mandatory hydrological package that increases landscape buffering capacity and reduces water intensity per unit of output. In operational terms, this requires reserving and legally securing space for retention elements (wetlands restoration where feasible, floodplain-compatible areas, polder-type solutions in appropriate lowlands), implementing controlled drainage in reclaimed landscapes, establishing riparian and field-edge buffer strips, and deploying distributed small-retention features within consolidated field blocks. Consolidation performance should therefore be evaluated not only by classical indicators (reduced fragmentation, improved access, lower travel time and operational costs), but also by quantified water-security outcomes: reduced virtual-water intensity (m^3 per tonne and, where possible, m^3 per unit export value) for the dominant export crops, explicit targets for retention coverage and buffer length/area, and measurable reductions in runoff and diffuse pollution risk at block or catchment scale. To ensure that such outcomes are technically feasible, consolidation should be financed and implemented as an integrated package combining parcel restructuring with road infrastructure, drainage/irrigation modernisation and green infrastructure, rather than as isolated boundary reconfiguration. Finally, Ukraine should prioritise pilots using hydrological risk criteria (drought-prone regions, catchments with high runoff pressure, areas with degraded melioration systems) and condition programme scale-up on post-consolidation monitoring of yield performance, water-intensity proxies, water quality indicators for nutrient pressures, soil condition trends and the functional status of buffers/corridors.

For **Poland**, land consolidation can retain its primary emphasis on farm-structure improvement and territorial functionality, while addressing two critical constraints: procedural efficiency and climate-resilience integration. The practical priority is to shorten project cycles by reducing administrative bottlenecks through digitalisation, standardised documentation, clear statutory time limits for key stages and appeal-management designs that preserve rights

while limiting strategic blockage. At the same time, environmental integration should be strengthened as a standard component of consolidation—particularly in relation to erosion control, riparian protection, and distributed retention features in vulnerable zones—so that field structure, access roads and drainage layouts jointly support soil protection and water quality objectives. Poland should also continue expanding incentives for voluntary participation and land exchange, because cooperative mechanisms reduce transaction costs and improve social acceptance, thereby increasing implementation capacity at scale. Success metrics should remain anchored in competitiveness (accessibility, coherent field blocks, reduced machinery inefficiency), but complemented with systematic soil-erosion and water-quality risk screening as part of the standard project design package.

6.4. Legislative and procedural recommendations for Ukraine and the use of green public procurement (GPP) in land consolidation for Ukraine

Based on an analysis of EU directives and the needs of the Ukrainian agricultural sector, we propose the following framework for the implementation of land consolidation:

1. Legislative harmonisation

It is essential to harmonise Ukrainian legislation with EU standards, in particular Directive 2011/92/EU on environmental impact assessment (EIA) and the Water Framework Directive 2000/60/EC.

The Land Consolidation Act must explicitly require an environmental assessment of consolidation projects that takes into account the impact on biodiversity and water regime, not just the economic benefits of consolidation.

2. Institutional safeguards – the process cannot be managed by surveyors alone. A Permanent Commission for the Joint Management of Water and Land Resources needs to be established under the Ministry of Agricultural Policy.

This commission would approve plans for shared facilities (windbreaks, water areas) as part of land consolidation, thereby ensuring integrated resource management.

3. In accordance with the principles of decentralisation and strengthening local communities, the adjustment process must include:

Mandatory public consultations on proposals for new arrangements.

The possibility for small owners to acquire land closer to the built-up area of the municipality (support for family farms).

4. Given the lack of public funds, it is recommended to use a public-private partnership model.

Tenants (agroholdings) who invest in infrastructure as part of land consolidation (e.g. irrigation) could receive tax breaks or long-term lease guarantees, provided that they maintain a positive soil and water footprint balance.

Land consolidation in Ukraine should not be seen merely as a technical tool for enlarging plots. It must be a key instrument of state environmental policy, ensuring adaptation to climate change, increasing the efficiency of input use and preparing the Ukrainian land fund for integration into the EU single market.

The use of green public procurement (GPP) in land consolidation for Ukraine

Green public procurement (GPP) is a modern public administration tool that allows environmental, economic and social criteria to be integrated into public investment decisions. In the context of land consolidation (LC) or Ukrainian *zemlevporiadokvanny*, GPP has significant potential to shape the quality of landscape restoration, promote sustainable land management, reduce environmental pressure and strengthen adaptation to climate change.

Ukraine is undergoing a profound transformation of its public administration, infrastructure, land markets and agrosystems, with war damage and extensive environmental damage to the territory creating a need for restoration based on the principles of *Build Back Better*, ecological security, sustainability and the circular economy. In this environment, the GPP is not only a modern method of public procurement, but also a strategic framework for the country's recovery, harmonising state processes with European Union standards.

Land consolidation is an important area in the state-managed agriculture sector, which can significantly contribute to the transformation of agriculture and the protection of biodiversity in our country, which is also the objective of the European Green Deal.

Given that the selection and financing of land consolidation contractors is usually carried out from the state budget, it is necessary to ensure that contractors for the services in question are selected through public procurement, with the possible application of green public procurement, which, in addition to its positive impact on environmental protection, also offers the possibility of using life-cycle cost criteria or environmental characteristics focused on elements of the circular economy . The contracting authority for land consolidation is the relevant ministry or, where applicable, the municipalities in the cadastral areas where the land consolidation is to be carried out.

Given the significant share of public procurement in European economies, which is approximately 14% of GDP in the European Union, public procurement appears to be a

powerful tool for promoting environmental, social and innovation objectives and stimulating access to public procurement for small and medium-sized enterprises. [181]

The strategic importance of GPP in the context of Ukrainian land management

Land consolidation in Ukraine is a public administration process similar to the Slovak model. Its aim is to ensure a fair and functional arrangement of ownership and usage rights, restore the ecological stability of the territory, eliminate land fragmentation, build common facilities and shape a sustainable landscape.

Based on an analytical overview of these works, it was concluded that the basis for the formation of special land management functions should be the properties of the land. First and foremost, land is the most important part of the environment, which is characterised by space and relief, climate and soil cover, vegetation, water and subsoil. It is the main means of production in agriculture and forestry, as well as the spatial basis for the location of objects of all sectors and spheres of the national economy. [182]

In the context of Ukraine, the GPP plays a strategic role in the LC for the following reasons:

1. Ecological and landscape stabilisation reasons

- restoration of land and landscape destroyed by military intervention,
- strengthening biodiversity and ecological connectivity,
- adaptation of the landscape to extreme climate events,
- revitalisation of the water regime.

2. Economic and circular reasons

- recycling and reuse of materials (SDO, excavated soil),
- reduction of life cycle costs (LCC),
- reducing the carbon footprint.

3. Modernisation and institutional reasons

- alignment with European standards,
- strengthening transparency and trust among international donors,
- modernisation of public administration processes.

The GPP is fully compatible with the principles of Ukraine's recovery and integration into the EU.

Legislative and institutional framework for adaptation in Ukraine

When transferring elements of green public procurement to land management in Ukraine, the following should be taken into account in particular:

- the Law of Ukraine on Public Procurement (Про публічні закупівлі),
- The Land Code and land market reform after 2021,
- the process of harmonisation with EU Directive 2014/24/EU.

Key adaptation elements:

1. Implementation of MEAT criteria

- transition from «lowest price» to the principle of *the most economically advantageous tender*,
- integration of environmental criteria into the evaluation.

2. Circular economy

- use of recycled materials,
- recycling of SDO from destroyed infrastructure,
- minimisation of transport and emissions.

3. Digitalisation

- use of electronic public procurement (e-PP),
- use of GIS for planning and monitoring,
- transparent monitoring of environmental parameters.

Implementation of green aspects in public procurement contracts

For a contract to be green, it is sufficient to apply green requirements in one of the parts of the tender documentation, which are:

- subject of the contract
- conditions of participation
- criteria for evaluating tenders
- contractual conditions.

In contracts procured through procedures under the Public Procurement Act (PPA) whose subject matter is land consolidation, the following CPV codes[183] are used, which represent an international nomenclature on the basis of which it is possible to clearly identify the subject matter of public procurement. (In the case of a combination of land consolidation and construction works, additional relevant CPV codes are added).

CPV codes for land consolidation

CPV code	Product
71300000-1	Engineering services
71250000-5	Architectural and engineering services and supervision

Source: author's own work

Four main areas of application of GPP in LC:

1. Subject of the contract
2. Conditions for participation
3. Criteria for evaluating tenders (MEAT / LCC)
4. Contractual conditions

A. Green subject matter of the contract

Obligation to define the subject matter of the contract in such a way as to promote ecological stability, nature-friendly solutions and sustainable management.

For Ukraine, this means:

1. Materials – use of recycled materials with environmental certification, preference for local materials with short transport distances.

2. Nature-based solutions - anti-erosion measures, hedgerows, biocorridors, honey strips, water retention and adaptation measures (windbreaks, wetlands, polders).

3. Areas contaminated by military activity – certified pyrotechnic work.

environmental supervision during demining, minimising interference with the soil profile.

In the case of land consolidation carried out with the aim of:

1. ensure the efficiency of agricultural land,
2. create access to land via roads in a way that preserves biodiversity and protects the environment,

3. creating land for greenfields and reusing brownfield sites, which will have a positive impact on environmental protection.

B. Green conditions for participation

The contracting authority may define the conditions for participation that are appropriate for use in public procurement of land consolidation contracts by demonstrating compliance with

technical and professional competence requirements through the following environmental labels and certificates.

Environmental labels



EU Ecolabel – a system designed to encourage businesses to market products and services that are more environmentally friendly and to make them easily identifiable to European consumers (including public and private purchasers)



Carbon neutral product – the Carbon Neutral certification programme requires an initial carbon audit in the form of a life cycle analysis – a comprehensive carbon audit that calculates the CO₂ emissions used in raw materials, fuels, electricity and waste used in the production and distribution of this product.



Environmentally friendly product

Certificates

Environmental certification declares that environmentally friendly solutions are used in the production, use and recycling of the product throughout its life cycle.

ISO 9001 Quality control system

ISO 14001 Environmental management system

ISO 14040 Environmental management – Life cycle assessment – Principles and framework

ISO 14067 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification



The Environmental Management and Audit Scheme is a voluntary European Union tool designed for organisations to help them evaluate, manage and improve their environmental performance.

Competencies of the project manager and project team

In the case of land consolidation carried out for the creation of roads, the following conditions of participation may be applied: Competences of the project manager and project team.

The project manager, engineers, architects, consortium of consultants and project teams must have the relevant competences and experience in each of these areas for which their members would be responsible within the contract and select according to what is appropriate for the specific contract:

- contracts for the management of road construction and maintenance projects that would bring about a better level of environmental protection;

- assessment of the environmental characteristics of roads using multi-criteria certification systems and carbon footprint tools in accordance with ISO 14067 or an equivalent standard;

- specification, procurement and use of construction materials with low environmental impact;
- use of construction materials with high recycled or reused content and by-products from road construction and maintenance;
- plans to reduce traffic congestion and LCC analysis [184] to determine the cost-optimal solution;
- real solutions to mitigate road traffic noise through low-noise pavements and noise barriers;
- increasing the durability of road surface layers, load-bearing capacity and fatigue resistance;
- development and implementation of monitoring and maintenance plans in real-life situations;
- design and installation of rainwater pollution control components and rainwater retention capacity, ideally including lightweight structural solutions for the drainage system.

It is necessary to emphasise experience with projects and continuous professional development in these areas. Depending on the nature of the project, the contracting authority may increase the number of years for which technical evidence must be provided and may require proof of a minimum number of contracts.

Evidence in the form of information and references to relevant contracts in the previous 5 years in which the above elements were implemented. This will be supplemented by the CVs of the staff who will be working on the project. [185]

References from project team experts

Under the conditions of participation, depending on the estimated value of the contract and the procedure chosen in accordance with the Public Procurement Act, it is common practice to request references from experts who will perform the subject of the contract. In most cases, the financial value of the references that a particular expert is required to submit as part of their bid is determined either as references within the subject matter of the contract as a whole, e.g. spatial planning, or as a specific part of the subject matter of the contract, e.g. landscape planning with the aim of constructing an irrigation system in the area in question, land improvement, prevention of deforestation and many other activities that are

C. Green criteria for evaluating bids

Public procurement distinguishes between three types of evaluation criteria:

- a) best price-quality ratio,

- b) costs using a cost-effectiveness approach, in particular life-cycle costs, or
- c) lowest price

Green criteria are applied in cases a) and b), where option a) is more commonly used in practice in the composition of 70% price + 30% other evaluation criteria (e.g. points for environmental references from experts in the performance of the contract – the tender documentation specifies the points awarded for each reference, the use of environmentally friendly technologies (equipment in the performance of the contract, etc.). [186]

In the case of land consolidation carried out for the purpose of creating roads, the following criteria, which are set out in the environmental characteristics issued by the European Commission in the field of road design, construction and maintenance, may be used for evaluation:

Inclusion of recycled content

If the impact of the road use phase is to be considered, this criterion is used in combination with the criterion for evaluating tenders. Requirements relating to fuel consumption due to rolling resistance. [187]

Points will be awarded based on improvements in the carbon footprint of the route, including at least the main elements of the route included in table a) compared to the reference route or other competing projects. The basis for comparison must be specified in the call for tenders. The characteristics shall be assessed by performing a carbon footprint (CF) in accordance with ISO 14067 or equivalent. The tenderer’s bid with the lowest carbon footprint shall be designated as the winning bid.

Table 6.7

Scope of road elements to be assessed

New construction or major extension	Maintenance and rehabilitation
Substrate, including earthworks	Foundation, binder and surface or concrete panels
Substrate	
Base, binder and surface or concrete panels	
Additional auxiliary road elements (optional)	

Source: [188]

Properties are assessed by calculating the carbon footprint (CF) in accordance with ISO 14067 or equivalent.

The project team or tenderer in the case of a contract awarded using the Design and Build (DB) method [189] or the tenderer in the case of a contract awarded using the Design, Built and

Operate (DBO) method [190] shall provide a list of materials for the proposed project and the CF results, which shall be reported in accordance with ISO 14067 or an equivalent standard. The comparison with the reference route shall be detailed in a brief technical report comparing the proposed design options and calculating the potential for improvement. The delivery document will be used by the contracting authority for future calls for tenders in the case of a separate design and construction contract, or will be updated and further improved by the main contractor or by the contractor in the case of a contract awarded using the DB method, or by the contractor in the case of a contract awarded using the DBO method, before the start of the construction phase. The successful tenderer will conclude the design phase by preparing the handover document. The successful tenderer in the case of a contract awarded using the DB method or the tenderer in the case of a contract awarded using the DBO method shall prepare the handover document before the start of the construction phase.

Life cycle assessment characteristics of the main elements of the road

The contracting authority shall award points to tenderers whose recycled content, reused content and/or by-products represent at least 15% of the total main road elements in Table c). The minimum content requirement for the allocation of points may be set higher if agreed with the project team prior to the public procurement of the main contractor. The contracting authority may decide, based on specific local conditions, to award more points for reused content than for recycled content. [191]

Table 6.8

Scope of road elements to be assessed

New construction or extensive expansion	Maintenance and rehabilitation
Subgrade, including earthworks	Base, binder and surface or concrete panels
Sub-base	
Substrate, binder and surface or concrete panels	

Source: [192]

The content of recycled and reused materials is calculated based on the average mass balance of reused, recycled materials and/or by-products according to the method of their production and delivery to the construction site.

The project team or tenderer in the case of a contract awarded by the DB method, or the tenderer in the case of a contract awarded by the DBO method, shall propose the amount of recycled content, reused content and/or by-products and shall quantify the proportion of recycled

or reused material in the total weight of the specified road elements based on information provided by the manufacturer(s) of the construction material. The project team or tenderer in the case of a contract awarded using the DB method or the tenderer in the case of a contract awarded using the DBO method shall describe the method of calculation and verification of recycled content, including at least batch documentation such as type test reports, documentation on production control at the plant and documentation relating to delivery and the method of verification by a third party during the construction phase.

Life cycle assessment characteristics of main road elements [193]

The contracting authority shall award points to tenderers whose recycled content, reused content and/or by-products represent at least 15% of the total main elements of the road in Table (c). The minimum content requirement for awarding points could be set higher if agreed with the project team prior to the public procurement of the main contractor. The contracting authority may decide to award more points for reused content than for recycled content, based on specific local conditions.

Table 6.9

Scope of road elements to be assessed

New construction or extensive expansion	Maintenance and rehabilitation
Subgrade, including earthworks	Base, binder and surface or concrete panels
Sub-base	
Foundation, binder and surface or concrete panels	

Source: [192]

The content of recycled and reused materials is calculated based on the average mass balance of reused, recycled materials and/or by-products according to the method of their production and delivery to the construction site.

The project team or tenderer in the case of a contract awarded by the DB method, or the tenderer in the case of a contract awarded by the DBO method, shall propose the amount of recycled content, reused content and/or by-products and shall quantify the proportion of recycled or reused material in the total weight of the specified road elements based on information provided by the manufacturer(s) of the construction material. The project team or tenderer in the case of a contract awarded using the DB method or the tenderer in the case of a contract awarded using the DBO method shall describe the method of calculation and verification of recycled content, including at least batch documentation such as type test reports, documentation on production

control at the plant and documentation relating to delivery and the method of verification by a third party during the construction phase.

Life cycle costs

Life cycle cost (LCC) calculation is a method that takes into account all costs that will be incurred for the subject of the contract during its lifetime.

The EU's GPP[194] criteria for road design, construction and maintenance will have a positive impact on some key factors affecting the overall life-cycle costs of roads. These factors are briefly summarised below with reference to the main variables in the life cycle costs of a road, noting that the potential benefits will always depend on the specific characteristics of each project. Reducing costs to society for specific environmental impacts (environmental externalities) can also be achieved by applying criteria such as [195]:

- The rolling resistance criteria related to road structure and surface roughness are directly linked to vehicle fuel consumption during the road use phase (a 10% reduction in rolling resistance can lead to a 1 to 2% reduction in fuel consumption) and thus also to greenhouse gas emissions. This also brings economic benefits for road users (drivers).

- Criteria aimed at reducing traffic congestion are designed to reduce additional fuel consumption and air emissions associated with traffic congestion, which can be a significant part of road costs over the life cycle, especially in the case of motorways and expressways.

- Criteria relating to environmental noise have an impact on human health and broader economic factors such as property values. The external costs of noise emissions from passenger cars in road traffic are estimated at an average of €2/1000 passenger-kilometres and from heavy goods vehicles at €2.5/1000 tonne-kilometres – estimated at a total of approximately €20 billion in 2008 in the EU-28. [196]

- Criteria for drainage systems («hard» or «soft» construction solutions) can help reduce the risk of flooding. Currently, flood damage in the EU is estimated at €5.3 to €6.4 billion per year, negatively affecting the lives of 200,000 people annually . A recent study by the Commission's Joint Research Centre estimates that the annual cost of this damage could increase seven- to eightfold by 2050, reaching EUR 40 billion and adversely affecting the lives of 500,000 people each year.

Slovak recommendations:

70% price + 30% environmental criteria,

or

LCC – life cycle costs.

It is also possible to set criteria based on a number of variations in use as one of the main criteria for the use of equipment in the performance of the contract, which have a positive impact on the environment, do not produce emissions into the air, are recycled or recyclable. For each such device, the contracting authority may allocate x% within the evaluation criteria, with the emphasis remaining on the price criterion, which also enters into the evaluation process. (e.g. price max. 75% + equipment with a positive impact on the environment max. 25% of the evaluation criteria).

Table 6.10

Examples of criteria for Ukraine:

Area	Example of criterion
Biodiversity	% of native species
Circular economy	% of recycled materials in roads
Energy efficiency	Proven CO ₂ reduction according to ISO 14067
LCC	Maintenance costs over 10 years

Source: Author's own processing

Slovak GPP criteria for road construction (recycled content, rolling resistance, noise, drainage) are fully applicable to Ukraine.

D. Green contract conditions

When applying green contract conditions to land consolidation, it is possible to choose from the following options, for example:

1. The contractor shall ensure that its employees/subcontractors travel to the land consolidation site outside rush hour in order to eliminate air pollution.
2. For the necessary landscaping modifications related to environmental protection and biodiversity, the contractor shall use local natural materials or the nearest available materials, e.g. aggregate for the construction of polders and embankments.
3. Inclusion of recycled content - When materials are delivered to the construction site, claims regarding recycled material with clear traceability must be verified for each batch of products. The main contractor or the contractor in the case of a DB contract or the contractor in the case of a DBO contract is required to verify the claims by providing either:
 - certificates from an independent third party on traceability and mass balance for the product and/or recycled product,
 - or equivalent documentation provided by the manufacturer(s).

4. Implementation of the plan for handling excavated material and soil - The main contractor or contractor in the case of a DB contract, or the contractor in the case of a DBO contract, is required to implement a system for monitoring and reporting measures involving excavated material and soil during construction work on the site. This system must include data on the weight generated (topsoil and excavated material), the percentage of reused/recycled materials on site and the percentage of reused/recycled materials off site. The system must also monitor and verify the destination of excavated material. Monitoring and tracking data shall be provided to the contracting authority on a regular basis according to an agreed schedule. In cases of necessary significant deviations from the excavated material and soil management plan proposed during the design phase, the main construction contractor or the contractor in the case of a DB contract or the contractor in the case of a DBO contract must inform the contracting authority, and any justified deviation must be approved [197].

5. Inspection of water pollution control components in the drainage system - The supplier is obliged to carry out an on-site inspection to determine the dimensions of the drainage system, walkways and connections between the components of the drainage system, and to verify that they comply with the project plans. The information shall be sent to the contracting authority according to the agreed schedule [198].

6. Inspection of rainwater retention capacity in drainage systems containing «soft construction» components - The main contractor or contractor in the case of a DB contract, or the contractor in the case of a DBO contract, is required to carry out an on-site inspection before and after the installation of vegetation-covered drainage components and to ensure that appropriate measures are taken in accordance with the guidelines on best practices for the creation of vegetation-covered covers on SuDS drainage components [199].

7. Implementation of the environmental integration and restoration plan - The main contractor or contractor in the case of a DB contract, or the contractor in the case of a DBO contract, is required to inspect the construction site during this work to ensure that the plan has been implemented. The main contractor or the contractor in the case of a DB contract or the contractor in the case of a DBO contract is required to carry out a final site inspection after completion of this work to ensure that the plan and any agreed deviations have been implemented [200].

Proposals for streamlining public procurement in land consolidation – Results:

1. Use of in-house contracts
2. Market consultations

3. Use of DNS
4. Appropriate price setting through price clauses
5. Quality assessment as one of the criteria in the future
6. Conditions of participation – use of experts

Ukrainian law PPL-20 (2015, amended) allows contracting authorities to include environmental (or other non-price) criteria in calls for tenders – for goods, services and works.

Since the change under PPL-20, it has been clearly established that public procurement may use «non-price criteria» (i.e. not only price, but also quality, life cycle, environmental parameters, etc.) – and it is no longer a condition that these are «complex or specialised contracts».

In the public procurement system (ProZorro platform), since April 2023, it has been possible to label a contract as «green/ecological». If this label is used, environmental criteria are considered «mandatory» (not just optional) in the evaluation [201].

A so-called «SPP» (Sustainable Public Procurement) catalogue of criteria (ecological standards according to Ukrainian/international standards) has been developed for 15 categories of goods and services.

We outline the possibilities for applying green aspects in land consolidation contracts in the subject of the contract, conditions of participation, criteria for evaluating bids and in the contractual conditions. Most problems do not require legislative change but rather an internal approach to setting professional conditions for land consolidation contracts, the composition of tender evaluation committees from experts in public procurement, and the continuous addition of professional capacity.

With increasing environmental awareness at present, it is becoming clear that the search for environmentally sound solutions in general, and also in the field of land consolidation, will be essential if we want to restart the country's economy, where the circular economy can help us to a large extent, the appreciation of natural resources, their protection and the reduction of unnecessary waste.

For effective enforcement, the GPP should include:

- the obligation to monitor the carbon footprint (fuel consumption, CO₂),
- reports on the management of excavated soil,
- control of recycled material content,
- environmental penalties for violations.
- mandatory publication of reports,
- use of real-time GIS monitoring,
- environmental supervision.

Institutional and expert requirements

For the successful application of green public procurement conditions to land consolidation in Ukraine, we recommend adherence to the following application options:

1. Multidisciplinary committees – it is recommended that experts in the following fields be represented: public procurement, ecology, soil science, hydrology, GIS and geoinformatics, circular economy, and post-military contamination landscape management.

2. Professional training – training must cover: MEAT and LCC, environmental criteria, material certification, GIS, drones, remote sensing, NBS and green infrastructure.

3. Digitalisation and transparency – project monitoring in GIS, public databases of environmental results, open-data approaches to strengthen donor confidence.

The expanded Chapter 6.4 presents an integrated framework for adapting GPP to Ukrainian conditions. It links Slovak practice, European standards, ecological and climate priorities, the context of post-war reconstruction, and the need for transparent and modern land management. Thanks to the comprehensive interconnection of ecological, legislative, technical and institutional measures, the chapter provides a clear basis for the systematic introduction of GPP into *land management* processes in Ukraine.

Practical examples of green public procurement in land consolidation

1. Denmark

Financing model and mandatory environmental targets

Denmark, which has a strong tradition of integrating nature conservation into agricultural policy, uses financial incentives and mandatory environmental conditions to ensure that farms also serve ecological objectives.

Best practices:

The most important element of conditional subsidies – The Danish system makes 100% public funding of planning, surveying and registration costs conditional on the LC project meeting specific environmental or nature conservation criteria [202]. If the project primarily serves environmental objectives (e.g. flood protection, wetland restoration), the procurement may be fully financed by the state [203].

- Application of the Public Procurement Act: Procurement focuses on the result – the creation or restoration of ecological structure – with financial criteria linked to the achievement of the environmental objective.

Role of the Ministry of the Environment: These authorities often act as contracting authorities for public works projects aimed at water protection. This ensures the direct implementation of environmental criteria in the tender documentation.

MEAT Criteria - the assessment focuses on:

- NBS scope - percentage of land reserved for nature-based solutions (biocorridors, windbreaks).

2. Germany

Multifunctionality and life cycle cost (LCC) model

The German land consolidation model (*Flurbereinigung*) is known for its multifunctionality, where the goal is not only economic optimisation, but also improvement of the landscape structure, flood protection and restoration of biodiversity [204].

Best practices:

Mandatory LCC analysis in construction contracts: Life cycle costs (LCC) are routinely used in the procurement of construction works (field roads, land improvement) within land consolidation. Not only the purchase price is evaluated, but also maintenance costs and longevity.

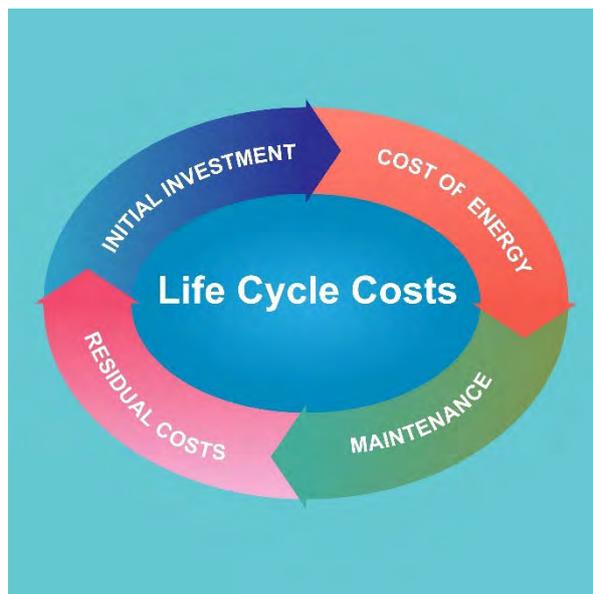


Fig. 6. 1: Life cycle costs. Source: Author's own work

Preference is given to solutions that have lower total cost of ownership over a 20-30 year cycle.

Environmental LCC (Social Life Cycle Assessment) – German methodologies also develop so-called social and environmental LCC, which take into account the impacts on biodiversity and social aspects when evaluating bids

Integration into nature conservation tools LC are mandatorily used to create ecological compensation measures for species protection (e.g. reptiles associated with vineyard terraces) and their provision becomes part of the tender documentation [205].

Qualification requirements for contractors in environmentally sensitive areas often require proof of environmental qualifications, e.g. ISO 14001 (Environmental Management) certificates.

3. The Netherlands

Circular economy (CE) model and innovation

The Netherlands is a pioneer in implementing the circular economy in public procurement [206]. Their approach is often performance-based GPP rather than strict technical specifications.

Best practices:

Performance-based criteria (Performance-Based GPP): Public procurers require that new roads and canals be built with minimal consumption of primary raw materials. Procurement measures environmental impact, not just compliance with standards.

CE indicator - MEAT criterion awards points for a high proportion of recycled construction and demolition waste (CDW) or for the reuse of excavated earth material directly in the project.

Low-emission mechanisation: Criteria for mechanisation with demonstrably low CO₂ and NO_x emissions are being introduced in tenders for earthworks. Preference is given to contractors who commit to using construction machinery that meets strict European standards (e.g. Stage V) or uses alternative fuels [207].

Innovative Partnership in complex LC projects uses a competitive dialogue process with the market, where the contracting authority seeks the best and most innovative sustainable solutions to hydrological and soil problems before the final award of the contract.

4. Slovakia

Multi-criteria assessment (MCA) model

The Slovak approach focuses on the objective prioritisation of projects and the integration of environmental values in the early stages of planning, which subsequently influences what is procured.

The multi-criteria assessment (MCA) mechanism is used for the semi-objective selection of cadastral areas for land consolidation. Instead of subjective selection, a set of criteria (geometric, ownership, environmental, erosion, morphological) is analysed [208].

Impact on GPP: This approach prioritises areas with the most significant environmental problems (e.g. low ecological stability, high erosion, flood risk) [209], which therefore require extensive eco-stabilisation and anti-erosion measures.

Subject of GPP: Procurement thus focuses directly on environmental structures and services (biocorridors, windbreaks, retention reservoirs, revitalisation of watercourses), making GPP an integral part of the Joint Facilities Plan.

Land valuation - MCH is also used to determine the indicative price of land in the context of reallocation, taking into account environmental factors such as the soil-ecological unit, location and development factor. This ensures that the environmental value of land is respected in the land consolidation process.

5. Austria

Comprehensive implementation model and EIA

Austria applies strict integration of environmental legislation into the land consolidation process, in particular through official assessment processes.

Environmental impact assessment (EIA): For complex and large-scale land consolidation projects, especially those involving infrastructure changes (roads, water management), an EIA is often mandatory [210]. The conclusions and requirements of the EIA become binding environmental specifications that must be reflected in the technical documentation for the procured works.

Financing green solutions - state aid schemes for the agricultural and forestry sectors (Rural Development Programme) allow up to 100% coverage of eligible costs for forestry land consolidation projects, provided that EU environmental and forestry criteria are met [211].

Impact on the EIA - such a high level of support removes economic barriers and stimulates the procurement of more expensive but environmentally optimal solutions and materials for the construction of field roads and erosion control measures (e.g. natural materials, sustainable drainage systems).

Multifunctionality of the area - land consolidation is seen as a tool for comprehensive area development, including flood protection and ecological stability, which directly influences the type of services and structures procured.

6. China

Model of ecological civilisation and strategic management

The Chinese approach is top-down, linked to ambitious national policies. Land consolidation is a key tool in the ecological civilisation strategy.

Linked to strategy – green public procurement (GPP) is not just an administrative process, but a means of achieving the goals set out in national plans. GPP actively creates demand for innovations and technologies with a lower environmental impact in the agricultural sector.

Procurement of results - instead of procuring only LC *services* (aimed at changing ownership relations), complex projects with measurable environmental results are procured. An example is the procurement of projects for the restoration and protection of degraded arable land,

where environmental criteria are key to the evaluation of bids and project effectiveness (e.g. improving soil production with a smaller ecological footprint) [212].

Strategic prioritisation - in procurement, preference is given to suppliers who demonstrate the ability to contribute to sustainable development goals and to reducing the environmental impact of agriculture, often associated with digital and innovative technologies

7. USA

Model of federal mandates and conservation programmes

There is no national equivalent of the European GP model in the USA. Green procurement is applied to federally funded natural resource conservation projects.

Federal Mandates for SPP: Sustainable Public Procurement (SPP) is applied, which requires federal agencies (such as the NRCS - Natural Resource Conservation Service) to purchase environmentally friendly products and services. This mandate takes precedence over all purchases related to land management programmes.

Procurement of «Best Management Practices» (BMPs): The NRCS procures and co-finances the application of specific BMPs on private agricultural land, focusing on erosion control, water conservation and biodiversity.

GPP criteria: In the procurement of works (e.g. construction of terraces, drainage systems, watercourse modification), specific environmental criteria are used for:

Materials: Requirements for recycled content, energy intensity of production (e.g. for concrete, steel).

Services: Use of environmentally certified fuels, low-emission construction machinery, proper management of construction waste.

Decentralisation with Centralised Guidance: Although projects are implemented at the local level, they are governed by federal guidelines and standards that ensure the uniform application of environmental requirements in procurement.

Conclusion and recommendations for the systemic integration of green public procurement into Ukrainian land consolidation

The final summary of Chapter VI - The Use of Green Public Procurement in Land Consolidation and Adaptation Proposal for Ukraine confirms that GPP is not just an optional environmental supplement, but an essential pillar of Ukraine's green reconstruction and institutional harmonisation with the European Union. The integration of GPP principles into land consolidation in Ukraine transforms this process from a purely technical and administrative activity into a catalyst for the country's resilience to climate change, biodiversity restoration and

the implementation of a circular economy. The key to success is the introduction of a systemic approach that overcomes the lowest price criterion in favour of life cycle costs (LCC) and the most economically advantageous tender (MEAT).

Based on an analysis of the Slovak methodology and the specifics of the Ukrainian legislative and post-conflict environment, the following key recommendations are formulated for the effective implementation of GPP into LC:

Recommendations for Ukraine

1. Legislative anchoring of GPP and MEAT - As part of the implementation of the Ukrainian Law on Public Procurement and harmonisation with EU Directive 2014/24/EU, bindingly define and expand environmental criteria and mandatorily apply MEAT criteria to all above-threshold and relevant below-threshold public procurement contracts, thereby overcoming the dominance of the lowest price criterion.

2. Implementation of the LCC Methodology - Mandatorily introduce the Life Cycle Cost (LCC) methodology when assessing all construction and technical projects within the LC, especially when constructing shared facilities (field roads, water management measures). This measure will ensure that public resources are spent on the most effective long-term solutions.

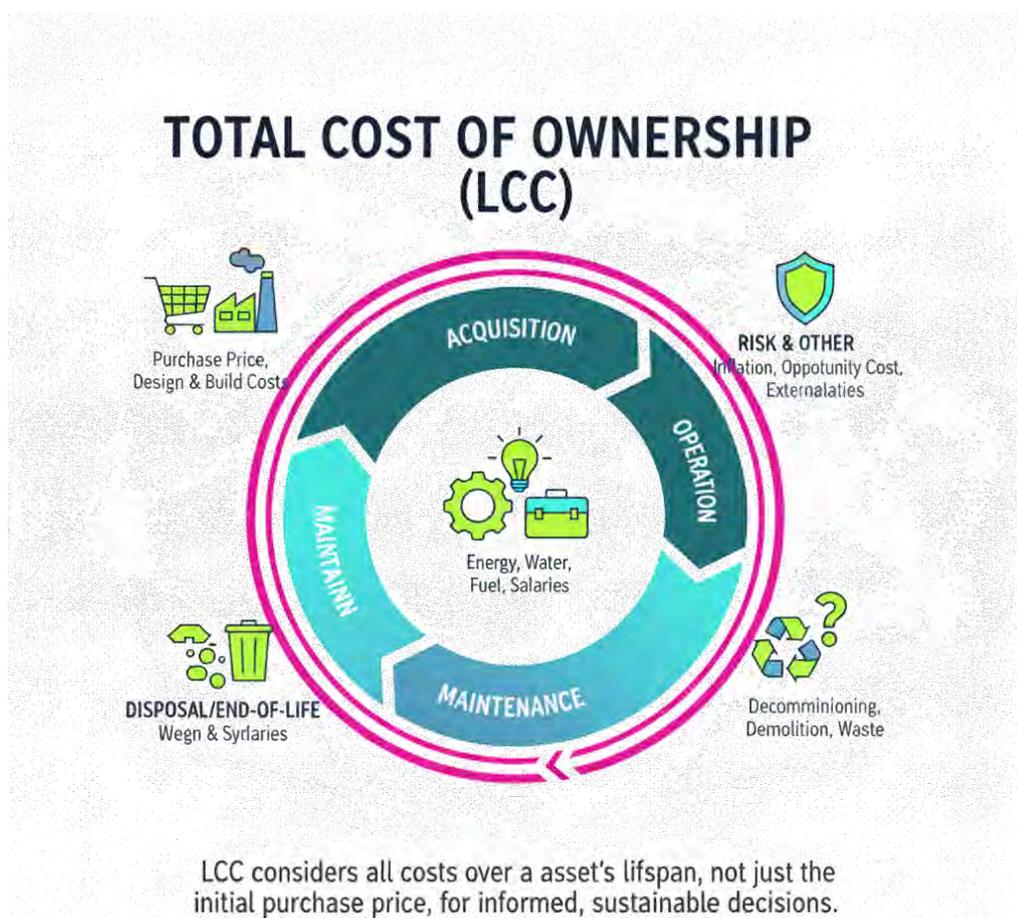


Figure 6.2 Life cycle costs. Source: Author's own work.

3. Prioritising the circular economy – explicitly incorporating requirements for the reuse and recycling of construction and demolition waste (CDW) destroyed by war into the technical specifications of public procurement contracts and a preference for local, environmentally certified and recycled materials, thereby reducing the carbon footprint and waste.

4. Integration of Nature-Based Solutions: Require that technical designs for erosion control and water retention measures prioritise Nature-Based Solutions (NBS) (windbreaks, biocorridors, wetlands, revitalisation) over hard engineering solutions. These solutions must be assessed through MEAT based on their contribution to biodiversity and long-term maintenance.

5. Specific GPP criterion for contaminated sites: For LC projects in areas affected by military activity, it is necessary to introduce a special criterion demonstrating environmentally friendly and certified procedures for pyrotechnic work with minimal disruption to the soil profile and environmental supervision.

6. Multidisciplinary evaluation committees - reform the composition of evaluation committees for public procurement contracts, which must include experts in public procurement, environmental law, soil science and GIS technologies to ensure the qualified implementation and evaluation of complex MEAT criteria.

7. Digitisation and GIS Monitoring - use e-VO platforms and geographic information systems (GIS) for transparent monitoring and control of compliance with environmental contract conditions (e.g. % recycling, status of biocorridors). Open-data publication of project results will increase transparency for international partners and donors.

8. Capacity development - introduce extensive and ongoing training programmes for civil servants and regional administration (zemlevporiadkuvannya) focusing on advanced topics: MEAT, LCC, ISO standards for carbon footprint and circular economy.

9. Mandatory Environmental Certificates - require suppliers to demonstrate environmental competence through ISO 14001 (Environmental Management) and/or equivalent certificates as a condition of participation.

10. Enforceability - strictly incorporate monitoring and sanction mechanisms for non-compliance with environmental commitments (e.g. pollution, improper waste management, non-compliance with NBS quality elements) into the contractual terms and conditions.

11. Harmonisation partnerships - use the experience of EU Member States (such as the Slovak Republic) in developing methodological guidelines and pilot projects for the rapid and effective adaptation of GPP into the Ukrainian legislative and implementation framework.

CONCLUSIONS

1. It has become apparent that the primary task in Ukraine is to justify the diversification of agricultural production under conditions that ensure the preservation of soil and water resources, particularly in the context of the emerging land market and the implementation of the Association Agreement between the EU and Ukraine. This includes: increasing investment in water management and the agricultural sector; supporting the production of competitive, high-quality products; diversifying agricultural production and exports towards high-value crops and finished products, while respecting the principles of the 'water' and 'land' footprints. These measures will contribute significantly to the implementation of the Association Agreement between the EU and Ukraine, state programmes for the development of the agricultural sector and regional development strategies for Ukraine and its regions.

2. An important experience for Ukraine is the adoption of the EU's conceptual approach to technical norms and standards, which form a key basis for the functioning of the EU single market. EU technical norms and standards define the basic requirements and criteria for assessing goods, services and processes. These standards have been proven to ensure that goods and services are fit for their intended purpose and compatible with human health, safety and environmental protection. The quality, safety, environmental and other requirements that the EU imposes on products entering its market are among the highest in the world. The removal of barriers to the movement of goods resulting from differences in national technical norms and standards between Member States is ensured in the EU in two ways: by harmonising national standards through the adoption and implementation of uniform legal standards in this area, and by applying the principle of mutual recognition. Key elements of European integration in ensuring the safety of agricultural environmental management are the use of life-cycle approaches, namely: setting targets to minimise the cumulative impact of products on the environment and taking into account the interlinkages between environmental aspects and different stages of the life cycle. Therefore, the basic guidelines for adapting Ukrainian legislative and regulatory documents in the field of environmental management, rational use of natural resources, ecological production of products and provision of quality services should include the use of EU experience in developing standards through technical committees. This concerns in particular the Scientific and Research Institute for Standardisation of the state-owned enterprise 'UkrNDNC', which is the leading institution of the Ministry of Economic Development and Trade of Ukraine in the field of standardisation, certification and quality and which shapes state policy in the field of standardisation and related areas.

3. It has been demonstrated that innovations related to environmental management safety in agriculture within the framework of adaptation, harmonisation and implementation of national

legislative and regulatory documents to EU requirements should take into account the following aspects: diversification opportunities within the domestic economy and needs arising from the international division of labour; the greening and socialisation of all economic factors in the production of goods and provision of services; the development of production potential (quality, growth rate, utilisation rate); product quality control, product cost levels and pricing; cooperation and regionalisation of agricultural enterprises based on soil, water and climate characteristics; development of local (unique) community and trade standards with protected geographical indications, etc. The future of the agricultural sector therefore lies in diversifying agricultural production by increasing the capitalisation and investment attractiveness of agricultural enterprises through the introduction of a functioning agricultural land market, support for family farms, introducing modern adaptive and environmentally friendly agricultural technologies based on the latest scientific and technological developments, taking into account regional natural and climatic conditions, and creating and implementing mechanisms to stimulate value added in local communities, which will contribute to the development of rural and populated communities.

4. For the agricultural sector, the most optimal option is a systemic (comprehensive) programme of European integration, which will ensure consistent administrative support for reforms and, at the same time, the restructuring and reduction of bureaucratic and budgetary structures and the consolidation of society around a system of widely accepted interests and priorities. This model is characterised by socio-ecological-economic management (economically efficient use and renewal of natural resources). Such a scenario is the most favourable and balanced and requires the implementation of green economy principles, systematic measures and the ability to adapt to external and internal challenges.

5. A concept for the ecological and economic security of agricultural management has been developed. It sets out ways to reform the Ukrainian economy so that it is socially responsible, environmentally safe and economically viable. This requires the introduction of ecologisation, digitalisation, socialisation and economic justification through a multi-level management system – from the global level to the level of small farmers and individuals (as users of natural resources and residents of specific communities). The concept introduces mechanisms for the intellectualisation of nature management activities and the implementation of a project-based approach within communities to ensure the efficient use of resources and increase budget revenues, secure livelihoods and, as a result, grow natural capital. It has been shown that the concept should be perceived as: a mechanism for ensuring ecological security across the entire sphere of nature management, including agricultural nature management, for a wide range of NPS stakeholders; a practical tool for regulating ecological and economic relations at both the macro and micro levels; a system of criteria for the macroeconomic evaluation of natural resources (from the state to the

municipal level) that takes into account the specifics of resource reproduction, systemic management of natural resources, and various types of management tools.

6. The foundations of state policy in the ecological and technogenic sphere have been laid in Ukraine. Specifically, institutional frameworks have been created, a regulatory and legal basis has been established in accordance with international standards and current needs, and a number of international agreements on environmental protection have been signed. However, the situation in this area remains quite complex. This is evidenced by long-term trends of deterioration in the ecological parameters of natural resources and the growing incidence of destructive processes affecting natural objects. These processes cause significant material losses, weaken the productivity of key natural resources necessary for life, and negatively affect public health. In view of the recommendations of the Environmental Security and Climate Change Adaptation Strategy for the period up to 2030 and our own observations, the strategic objectives for land and water use are as follows: ensuring the rational use of natural resources; achieving «good» ecological status of waters; improving the effectiveness of the state system of environmental impact assessment and state supervision (control) in the field of natural resource protection; strengthening the adaptive capacity and resilience of social, economic and ecological systems to climate change; restoring and stabilising the ecological balance in temporarily occupied territories after the restoration of Ukraine's territorial integrity within its internationally recognised borders; and integrating environmental security and climate change adaptation measures into national and regional strategies, river basin management plans and other strategic frameworks.

7. When water and land resources are used jointly, internal efficiency increases, costs and business risks are reduced, information exchange improves and business management reaches a new, higher level, leading to a significant reduction in transaction costs. The creation of functional mechanisms for the joint management of water and soil resources therefore requires effective and inclusive governance, as well as coordinated and integrated policy measures across different sectors. Such measures make it possible to address the numerous challenges associated with the use of natural resources, achieve the necessary compromises and preserve the state of the relevant ecosystems and the services they provide. Multi-level governance mechanisms are essential to ensure the effectiveness, efficiency and inclusiveness of land and water strategies. In addition, multi-stakeholder and interdisciplinary approaches involving the active participation of civil society, academia, local communities, young people and the private sector are key to developing a comprehensive land and water management system.

8. An analysis of innovations in the field of environmental safety in agriculture confirms that environmental certification within the framework of the safe use of agricultural nature is a logical continuation of the development of product and service certification, as well as the

systematic assurance of the integrated use of natural capital as a single resource. This process is still in its infancy, also in terms of addressing the country's social challenges. Damage reflected in economic or environmental indicators is equally undesirable for society, which is why a systematic assessment of the state of soil resources as part of natural capital is proposed. When planning agricultural activities, as well as activities in all other sectors, economic and environmental issues should therefore be addressed equally in terms of social interests. The safe use of agricultural nature also has a significant impact on the quality of ecosystem services (NPS), is one of the key parameters determining quality of life, and is therefore relevant to every individual, society and the country as a whole.

9. It is well established that environmental auditing and certification of agricultural land and agro-industrial enterprises are effective economic and environmental tools for ensuring the safety of production and consumption of environmentally friendly products. In essence, they represent an innovation in environmental management and an integral part of the characteristics of a sustainable development community. These practices are justified from both an environmental and economic point of view, as global economic growth is increasingly driven by the share of products and technologies based on modern innovative solutions. Environmental certification of the safe use of agricultural land will therefore bring synergistic effects at various levels, with the proposed methodological approach placing our country in the position of a major player in the food and energy crop markets. As a result of environmental certification of agricultural land, the «leakage» of working capital will be stopped, the «ageing» of fixed assets will be slowed down, and certified cereal production will become a stable source for other sectors of the Ukrainian economy.

10. The concepts and methods for calculating the «land» and «water» footprints in the context of climate change are well-founded. Information on virtual water and land consumption and trade enables sound decisions to be made in the field of agricultural environmental management and partially addresses the shortage of water and land resources – especially at the global level – by exporting water- and land-intensive goods from countries with high resource availability to countries with limited access. However, it is essential to consider the impact of foreign economic activity on the sustainability of water and land resources and on the overall state of the environment in the exporting country. The water and land footprints form the basis for drawing conclusions about the sustainable and equitable use and distribution of water and land resources. They also serve as a basis for assessing environmental, social and economic impacts at the regional level. Virtual trade in water and land will expand development opportunities for sectors producing land- and water-intensive goods, taking into account the availability of these resources in specific regions.

11. Land consolidation and its role in the effective management of agricultural land in the context of climate change and European integration, with an emphasis on the integration of green public procurement into land consolidation in Ukraine, confirms that green public procurement is a key pillar for Ukraine's green reconstruction and harmonisation with the European Union. For successful adaptation to the land consolidation process in Ukraine, it is essential that Ukraine abandon the lowest price criterion and switch to the most economically advantageous tender and life-cycle cost methodology. Key recommendations include the mandatory incorporation of circular economy principles – including the reuse of construction and demolition waste – and nature-based solutions in the design of water retention and erosion control measures. The introduction of criteria for environmentally friendly practices in the demining of contaminated sites requires specific attention. At the institutional level, it is essential to set up multidisciplinary evaluation committees (comprising public procurement experts, ecologists and hydrologists) and to strengthen the technical capacity of the Slovak Ministry of the Environment through targeted training. The entire process must be supported by digitisation and transparent online monitoring through Geographic Information Systems, which will increase the confidence of international partners and ensure the long-term sustainability of investments in the country.

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