Received: 08.02.2021. Revised: 09.10.2021. Accepted: 09.25.2021

EKONOMIKA APK

https://doi.org/10.32317/2221-1055.202109066

Ekonomika APK, 28(9), 66-81

UDC 338.244(332.2):338.24.01

Agricultural Land Use Management in the Context of a Non-Linear Approach

Larysa Kupinets*, Hanna Tiutiunnyk

Institute of Market and Economic-Ecological Research of the NAS of Ukraine
65000, 29, Frantsuzkyi Blvd, Odessa, Ukraine

▸ **Abstract.** Using land resources does not comply with the requirements of balanced nature management. Much of the land has lost its economic fertility through excessive cultivation and intensive degradation processes. The ecological condition of the land involved in agricultural use has deteriorated to such an extent that currently since land resources in agribusiness are used as a means of production, the economic condition of economic entities and the food security of the country depend on them. The purpose of the research – to develop a scientific vision of strategic land use management in the context of nonlinear changes based on the investigation of qualitative and quantitative features of soil processes, possible risks and modelling of development scenarios. A combination of methods, principles and techniques of scientific cognition was used: statistical analysis – in the description of long-term regional target programs for the protection and rational land use (environmentally friendly) on the example of the Black Sea region; comparative analysis – in determining the level of provision of the regions of Ukraine with ecologically safe lands, the state of the environment in the zone of ecologically safe land use, the provision of ecological areas and areas suitable for transformation, comparing the target values of agricultural land use areas under organic production; graphical – for visual display of the model of non-linear two-stage management of agricultural land use in conditions of uncertainty of its components. Proposed: ways to develop ecologically safe lands (organic) about target values, provisions and state of land use; interrelation of plans of target and existing state of land use; accounting of benefits and losses of achieving target values with an appropriate number of ecologically suitable land uses. The strategic vectors, areas and expected results of agrarian land use management in the context of a non-linear approach are determined. The scientific originality of the research lies in the substantiated algorithm of the model of nonlinear two-stage agrarian land use management under uncertainty. The miscalculations of state management of land resources as a prerequisite for strategic management of agrarian land use are substantiated. The model of nonlinear two-stage agrarian land use management under uncertainty is presented. The strategic vectors of agrarian land use management in the context of a non-linear approach are developed

▸ **Keywords:** strategic management, nonlinearity, strategising, sustainable development purposes, and modelling

▸ **Suggested Citation**: Kupinets, L., Dubas, R.H., & Tiutiunnyk, H. (2021). Agricultural land use management in the context of a non-linear approach. *Ekonomika APK*, 28(9), 66-81.

*Corresponding author

▸ Problem statement

One of the most significant objectives currently confronting the management of economic and ecological systems is the development of efficient management strategies to cope with the growing potential of complex and unexpected changes and at the same time preserve ecosystems (natural – marine, terrestrial, freshwater or artificial and anthropogenically modified ecosystems as a result of human economic activity, which can exist only with the support of the latter, as they are not self-sufficient and self-regulating and quickly collapse in the absence of such support).

In the economics of nature management, there is an understanding of such a category as "economic and ecological system". Economic-ecological systems are a specific class of systems where the main components are the economy and the environment. They are considered the integrity of ecological and economic systems, characterised by the presence of internal links and emergent properties.

The economic-ecological system is a naturally open, complex dissipative dynamic system with inherent properties of nonlinearity. According to the theory of complex systems, the main driving force for the development of economic and ecological systems is the conflict between its subsystems and elements. This conflict is constantly growing and is conditioned upon a large number of connections and functions, i.e., their complex hierarchy. However, the main conflict is the contradiction between the model of economic growth and resource consumption.

Nonlinearity is characterised by two processes. It is a stable disequilibrium of the entire system and a stable equilibrium of its subsystems. The first state is more difficult to maintain than the second. And this is the foundation for the development of managerial influences in the system of management hierarchy.

The necessity of changing the management paradigm is obvious, as anthropogenic pressure is growing, and economic activity significantly violates the stability of natural ecosystems. Thus, the objective is to switch to applying management strategies that consider the nonlinearity and non-equilibrium of such systems. However, the development of management strategies involves diagnosing the nonlinear dynamics of such systems, analysing their functioning and identifying trends that were not properly considered in conventional management approaches. It is the non-linear approach that can improve understanding and better organise sustainable management of economic and ecological systems for more efficient use of natural resources and improvement of living conditions of the population.

Although the predominance of mainly nonlinear and chaotic processes in the natural world is now established, the inclusion of these types of dynamics in management is still not considered. Ignoring these approaches can result in unexpected economic, environmental and social consequences.

Thus, the diagnosis of nonlinear processes is a prerequisite for the definition of new management approaches that can consider this type of dynamics.

The analysis of the development of economic-ecological systems has long identified the constraints between growth and the environment. Practice demonstrates the necessity of developing a new systemic understanding of the complexity of the economy and ecology, which, like any complex system, constantly reconfigures itself in response to any impacts, often with unforeseen or undesirable consequences. Complexity is a common feature of modern economic and environmental policy, which is developed in the context of growing consumption, the complexity of technologies and limited resources. The complexity of economic-ecological systems demonstrates nonlinear development and is manifested by unpredictable dynamics and uncontrolled behaviour.

The lack of consideration of the non-linear structure of agroecosystem development should be mentioned as the main drawback of the agricultural sector management system. Changing reactions in the structure of the agroecosystem occur unexpectedly, depending on the variety of natural factors that arise according to their unique laws. The unexpectedness of the reactions is due to long-term anthropogenic intervention that causes warming, environmental pollution, etc. Nonlinearity is an essential component of agroecosystem dynamics during the period when the system is between alternative states. The system is described by two influences – exogenous and endogenous, namely: internal laws of agroecosystems and external anthropogenic factors. The nonlinear system is indeterminate and

chaotic and requires substantiation of scenario options for adaptation of management and development of models of changes in agroecosystems by exogenous and endogenous influences. Models, in turn, require consideration of a wide range of components, a range of possible conditions, multiple development trajectories, adaptability, unpredictability, and variability in time and space.

The establishment of the land market and other transformations in the system of land ownership means a long-term process of development of even the most successful sectors, including agriculture. It requires the development of a global agricultural strategy highlighting potential participants and trends in the industry in the context of global challenges.

Management of the agrarian sector as a system has several disadvantages and causes, accordingly, the emergence of miscalculations: lack of proper development of mechanisms to stimulate landowners and land users in the rational and environmentally oriented use of land resources; land valuation without involving the environmental component; due to the universality of land use for all types of land, without regard to the specifics or local conditions of their use; neglect of the interests of land users, traditions, environmental experience.

Strategic management of agrarian land use in the context of a non-linear approach requires a preliminary assessment of current practices, the necessity of achieving the targets of the Sustainable Development Objectives and ecologically oriented land use.

▸ Analysis of recent studies and publications

According to the definition of A.I. Solovyov, the management of agricultural production is a complex, nonlinear multifactorial process, the modelling of which it is required to use modern tools and powerful nonlinear multidimensional methods based on artificial intelligence, based on neurotechnologies. It provides high reliability of approximation of highly complex processes in space and time, which are reflected in the universal scheme of the neural network (Soloviov, 2015).

According to A.O. Gutorov, most quantitative dependencies in the agricultural sector are nonlinear and the variability of parameters is within large limits (Hutorov, 2009). At this stage, there are practically no economic and mathematical models that reflect the specific features of the reproduction process in agriculture, in particular agricultural land use. Declaring the above statement, I.V. Khlivna emphasises its stochastic nature, interconnection of industries, nonlinearity and variability in economic conditions (Khlivna, 2013). Along with other prominent scientists, nonlinear dependence is distinguished by P. Kubach in the investigation of the development of agriculture and rural areas (Kubakh, 2021)

Using the results of nonlinear and global equivalent approximations for solving stochastic problems and comparing their accuracy with conventional linear and local equivalent methods was described in their work by Cai Yongyang, Judd Kenneth, and Steinbuks Jevgenijs (Cai, Judd, & Steinbuks, 2016). The nonlinear concept is chosen as a foundation by scientists Yan Zehao, Li Mo, and Li Zhong to develop a stochastic multi-objective model for irrigation water distribution under uncertain conditions. This approach balances the conflicting goals of maximising net economic benefit and natural resource efficiency. It may reflect the random nature of water availability and response to climate change (Yan, Li, & Li, 2021). Another opinion on using the concept of nonlinearity in the development of a control model for optimal management of agricultural irrigation water under uncertainty was proposed by Zhang C., Yue Q. and Guo P. (Zhang, Yue, & Guo, 2019).

A nonlinear model for optimising the allocation of water resources was developed by scientists: Aljanabi Ahmed A., Mays Larry W., and Fox Peter (Aljanabi, Mays, & Fox, 2018). Predictive management of natural resources based on nonlinearity is proposed in the work of scientists: Wu Z, Zhang Junfeng, Zhang Zhihao, Albalawi Fahad, Durand Helen, Mahmood Maaz, Mhaskar Prashant, Christofides Panagiotis D. (Wu, et al., 2018).

The purpose of the research – to develop a scientific vision of strategic land use management in the context of nonlinear changes based on the investigation of qualitative and quantitative features of soil processes, possible risks and modelling of development scenarios.

▸ Summary of the main results of the study

Land use as an ecological and economic system is dynamic. Its main element is a society with its economic and social subsystems. As a rule, it is a nonlinear system, with nonlinear interactions and nonlinear laws of development. Changes in ecosystems increase the probability of nonlinear transformations in the ecosystems themselves (Ministry of Economic Development…, 2017) (Fig. 1).

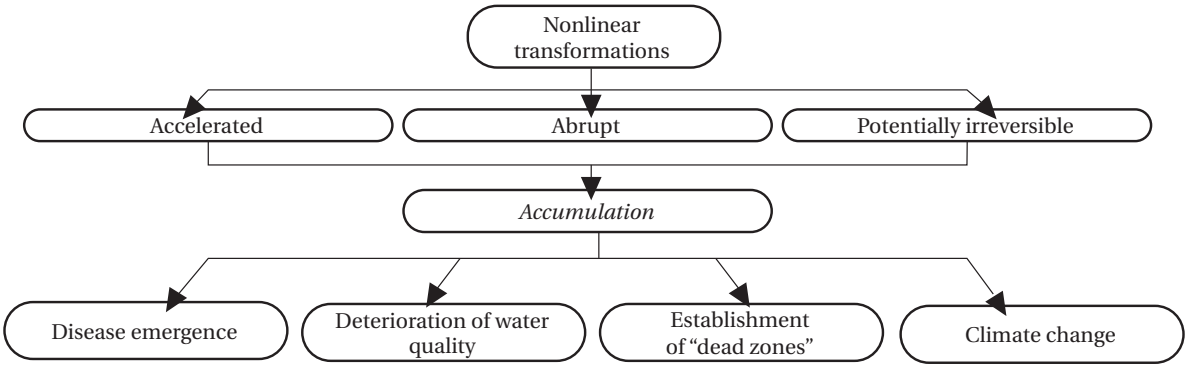

Figure 1. Typification and consequences of nonlinear transformations in land use
Source: Author's development

They are divided into accelerated, abrupt and potentially irreversible. The changes occurring in the system accumulate, as a result of which the system loses stability, moves to another trajectory and further develops within other stability limits. These changes are characterised by serious consequences for human welfare and health. Examples of such changes are the emergence of diseases, deterioration of water quality, the establishment of "dead zones" in coastal waters, etc. In ecosystems, they tend to occur progressively. When the threshold value is crossed, the system switches to a completely different state. Changes can be rather significant in magnitude, thus making them difficult, expensive or impossible to reverse. To prevent adverse impacts and develop scenarios for the development of agricultural land use, it is necessary to develop possible models of non-linear changes for the components of the agricultural sector (Fig. 2).

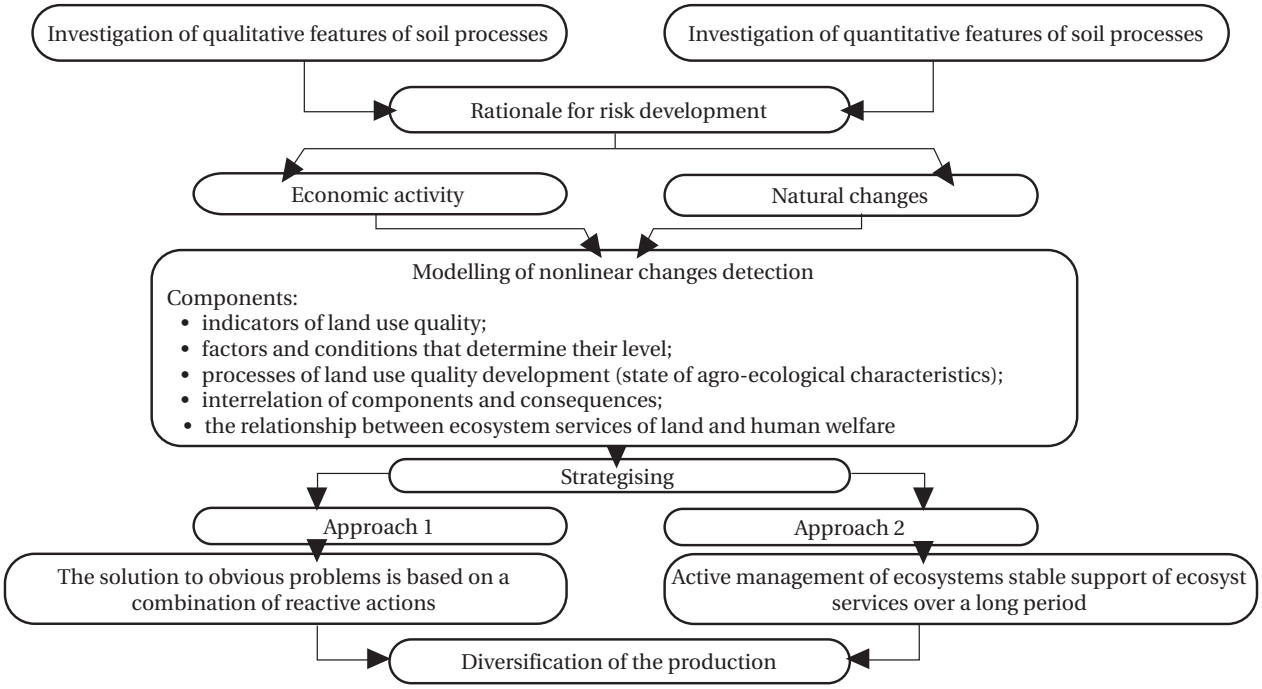

Figure 2. Stages of strategic land use management in the context of non-linear change
Source: author's development

First of all, this concerns land use, which requires a thorough investigation of both quantitative and qualitative characteristics of their development and possible risks. The specific quantitative and qualitative features of soil processes are considered. Natural changes and economic activity have a significant impact on soil processes, and through them on soil properties and fertility, i.e. its quality. It ensures further diversification of production in the relevant zones depending on the quantitative and qualitative characteristics of land resources, the geography of their location, resource capabilities and climatic features of natural zones.

Models for detecting non-linear changes are designed by the established standard of agroecological quality of the land mass, using agrotechnologies to obtain it, constant comparison of the obtained quality with the standard, and in case of deviations – implementation of measures for their transformation. The components of the models are indicators and processes of land use quality development, factors and conditions that determine their level, features and properties that affect the patterns of soil functioning and ensure the vital activity of plants, animals and humans (Tiutiunnyk, & Kupinets, 2020).

Strategic management should be based on two various approaches to ecosystem management: the first is developed based on a complex of reactive actions to eliminate adverse results of land use. According to this scenario, the most complicated problems are solved only after they are obvious; the second scenario involves active management of ecosystems with stable support of eco-system services before adverse results (soil development and primary production, water regulation and diseases, etc.) appear for a long period (Khlivna, 2013).

Non-linear management of agrarian land use is limited by the lack of information on the quality of land, imperfection of the cadastral database, and failure to consider the environmental component in land use assessment and economic calculations. The state of agricultural land use is recorded in statistical information collections based on land monitoring data. Strategic land management should be based on purpose setting, planning and forecasting. Accordingly, to improve the quality of management, predictive assessments of both the general state of the ecosystem and the impact of newly established land use are required, considering the (model) relationships between its components and possible consequences. Such models can be used to develop strategic decisions or adjust existing ones.

Scenario models for the purpose of further strategic management of agricultural land use include links between land ecosystem services and human welfare, which are, therefore, not linear. If ecosystem services are sufficient compared to the demand for them, the marginal increase in ecosystem services, as a rule, provides only a small contribution to the welfare of the population (Khlivna, 2013). However, when ecosystem services are scarce, a small impact in the field of their reduction can significantly reduce the available welfare.

The Resolution of the Cabinet of Ministers of Ukraine "On Development of Forecast and Program Documents of Economic and Social Development and Drafting of the Budget Declaration and the State Budget" of April 26, 2003, No. 621 (Law of Ukraine № 1264-XII, 2021) does not include environmental protection, use of natural resources and environmental safety in the list of economic sectors for which a five-year forecast is developed. However, in the Law of Ukraine "On Environmental Protection" of June 25, 1991, № 1264-XII (Law of Ukraine № 1264-XII, 2021) environmental protection management is defined as the implementation in this area of the functions of observation, research, strategic environmental assessment, environmental impact assessment, control, forecasting, programming, informing and other executive and administrative activities. The state environmental monitoring system is responsible for this (Fig. 3).

Article 22 of the Law of Ukraine "On Environmental Protection" of June 25, 1991, No. 1264-XII determines that state bodies together with relevant scientific institutions ensure the organisation of short-term and long-term forecasting of environmental changes, which should be considered in the development and implementation of programmes and measures for the economic and social development of Ukraine, including environmental protection, use and reproduction of natural resources and ensuring environmental safety.

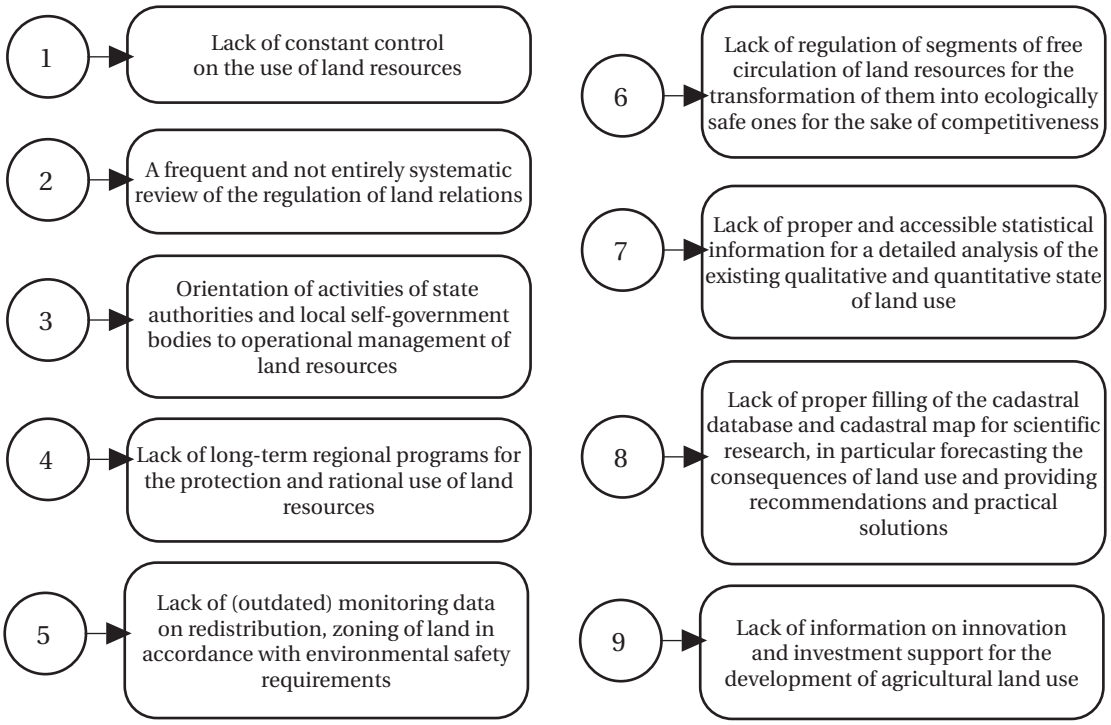

Figure 3. Miscalculations of state management of agrarian land use
Source: author's development

Forecast assessments, planning of rational land use and development of long-term programmes for the protection and rational land use (environmentally safe) in the Black Sea region have not been performed in recent years (Table 1).

Table 1. Availability of long-term regional target programmes on protection and rational land use (environmentally safe) on the example of the Black Sea region

Region	Number of regional programmes	Title
Odesa	0	-
Mikolaivska	0	-
Kherson	1	Regional programme on use and protection of land in Kherson region for 2020-2024

Source: Developed by the authors based on (List of regional target…, 2021)

It can be stated that there is a necessity to establish the concept of a comprehensive information resource, which contains coordinated information on all-natural properties of economic land use, actual and planned use, and forecast estimates.

Improvement of the land management process, including its institutional component in the short and long term, should consider both sustainable land use and socio-ecological, economic and informational development of agrarian land use. The rational use of land resources determines both their protection and conservation for the long term and reasonable use of the natural component, which is the key to the environmental stability and competitiveness of the regions and the country in general.

Tabular and illustrative data indicate a high level of provision of countries of the European Union by ecologically safe lands, namely organic ones, and, accordingly, about the low level in Ukraine, namely in the Black Sea region, which will be demonstrated below (Table 2-4, Fig. 4, 5).

Table 2. The level of provision of environmentally safe lands in the example of the Black Sea region, 2019

Region	Share of ecologically safe areas and suitable for ecotransformation in relation to the total area of the country, %.
Odesa	2.39
Mikolaivska	4.75
Kherson	0.56

Source: (Organic production in Ukraine, 2021; Ministry of Ecology…, 2020)

Table 3. The state of the environment in the zone of environmentally safe land use in 2019 on the example of the Black Sea region

Region	Characteristics of the ecological state of land use		
	Coefficient of environmental stability	Score of anthropogenic load	Environmental sustainability
Odesa	0.32	4	Environmentally unstable
Mikolaivska	0.29	4	Environmentally unstable
Kherson	0.34	3	Steadily unsustainable

Source: Developed by the authors based on (Ministry of Ecology…, 2020)

Less than 0.33 – the territory is ecologically unstable; from 0.34 to 0.50 – refers to stable unstable; from 0.51 to 0.66 – passes within the limits of medium stability; if exceeds 0.67 – the territory is ecologically stable.

2 points – a high degree of anthropogenic load (industrial land, transport, settlements); 4 points – significant (arable land, perennial plantations); 3 points – average (natural fodder lands, grassed beams); 2 points – minor (forest belts, shrubs, forests, swamps, under water); 1 score –low (micro-reserves). Ukraine occupies one of the last places compared to the European Union in terms of the share of areas of high natural quality.

Table 4. Indicators of provision of ecological areas and suitable for transformation into such areas in 2019

Region	Amount of land with ecologically safe soil quality indicators, %. of the total country territory
Odesa	2.00
Mikolaivska	0.53
Kherson	3.28

Source: (Organic production in Ukraine…, 2021; Ministry of Ecology…, 2020)

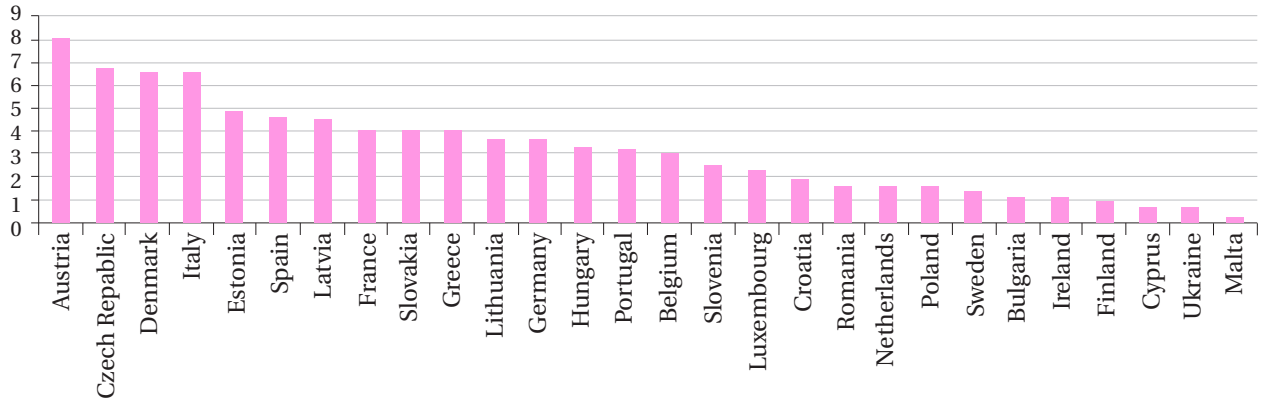

Figure 4. Share of organic areas to the total country's territory in 2019 in the EU, %.

Source: Developed by the authors based on (Kubakh, 2021)

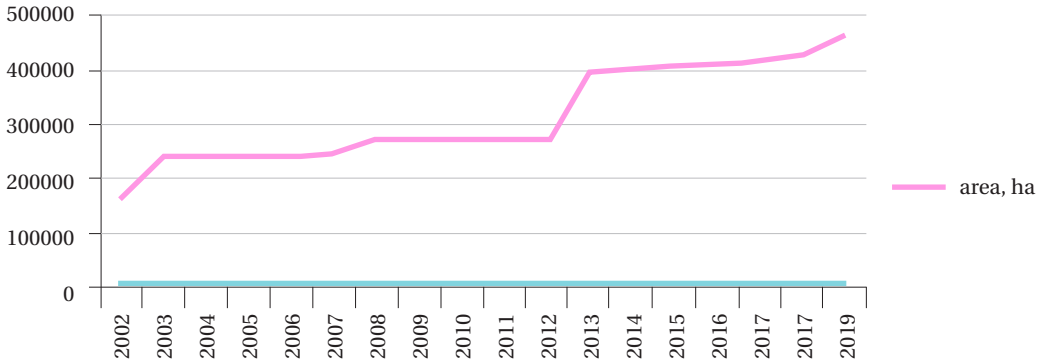

Figure 5. Dynamics of areas under organic agricultural lands in Ukraine, 2002-2019
Source: (List of regional target…, 2021)

It demonstrates the imperfection of the management system in the field of land use, its specific features as a complex system and the inefficiency of using the existing advantages of the properties of land resources of Ukraine. In addition, this is confirmed by the investigation of the state of the environment in the zone of ecologically safe land use based on the calculations of the coefficients of ecological stability of landscapes.

$$K_{esl} = F_{stab/}F_{unstab.},$$

where K_{esl} is the coefficient of ecological stability of landscapes, $F_{stab.}$ is the area of stable landscapes (forests, protective forest plantations, floodplain meadows, reserves, nature reserves, natural reservoirs, swamps, shrubs, pastures, hayfields, arable land under perennial crops); $F_{unstab.}$ – the area of unstable landscapes (land under construction, silted water bodies, mining sites, ravines, arable land under annual crops).

In the National Report "Sustainable Development Goals: Ukraine" (Ministry of Economic…, p. 109), within the framework of Goal 15

"Protection and restoration of terrestrial ecosystems", indicator 15.3.4. – the area of agricultural land under environmentally friendly, namely organic production, is represented by the following target values (Table 5).

Table 5. Target values of agricultural land use areas under organic production, 2015-2030

Year	2015	2020	2025	2030
Target value, area, ha	410.6	500	1500	3000
Growth rate, %	-	121.8	300.0	200.0

Source: (Ministry of Economic, 2017, p. 109)

Therefore, it becomes obvious that the rate of expansion of organic land areas from 2020 is significantly accelerating. Thus, in 2015, the area of land under organic production of 410.550 thousand hectares was described as satisfactory for the target value of 410.6 thousand hectares. In 2019, 467.980 thousand hectares compared to the target value of 500.0 thousand hectares in 2020, was considered as not optimally performed.

Significant changes are envisaged in 2025 – a threefold increase from the current state of organic land use, 2030 – twice the area of land in 2025.

However, achieving the targets may become problematic due to various risk situations, in particular, the implementation of climate change impacts, which is described as uncertain and non-linear.

The availability of suitable land for conversion to organic is regulated by several factors, the values of which cannot be known within a specific time interval. However, this does not prevent establishing the target function of maximising economic benefits and the system of constraints (Fig. 6).

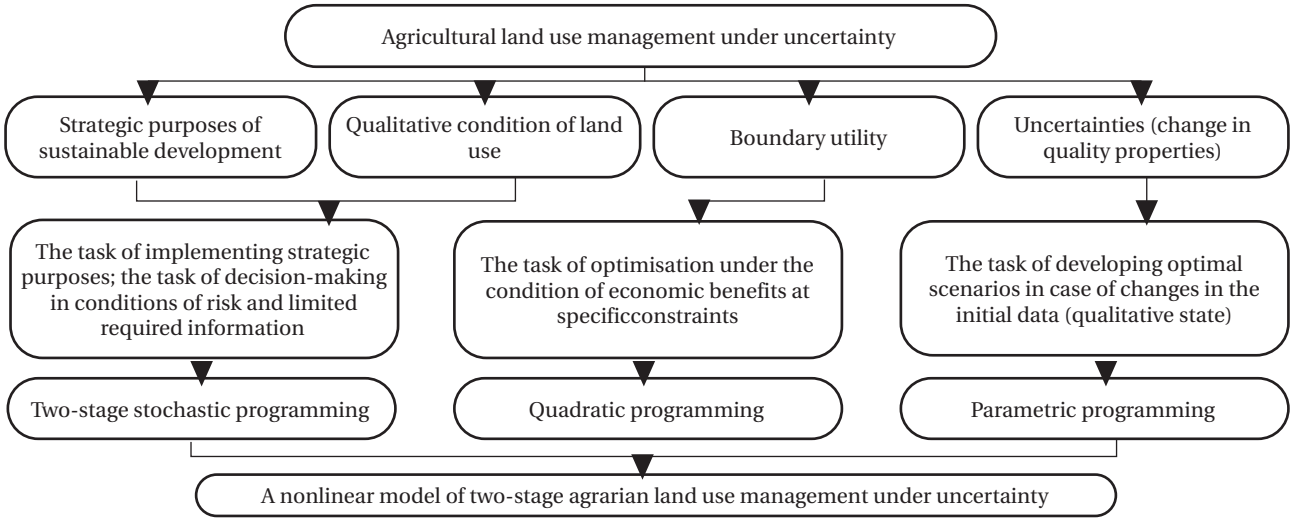

Figure 6. Model of nonlinear two-stage agrarian land use management under uncertainty

Source: Author's development using (Millennium Ecosystem Assessment, 2005; Organic crop area by…, 2012; Institute of Soil Protection..., n.d.)

Thus, information on the qualitative state of soils according to the latest research is presented in the time frame of 2011-2015 (Institute of Soil Protection..., n.d.). Full information is given in the National Report on the State of Soil Fertility of Ukraine in 2010 and periodic reports with insufficient information (Law of Ukraine № 1264-XII, 2021; 23).

The achievement of the targets specified in the Sustainable Development Goals is based on the justification of indicators for each area. According to the specific features of the territory, the results will vary.

Since the standard deviation of the information data is unknown and some data are completely missing, interval values are used. According to the developed scheme, several plans are required to establish environmentally safe land use (Fig. 7). Thus, the initial plan is used to determine the targets by years, the adjusted plan reflects the current state of land use. Only in the case of compliance with the adjusted and initial plans, it can be stated that the quantitative and qualitative indicators of land use have reached the target value. The task of achieving strategic purposes; the task of making decisions under conditions of risk and limited information.

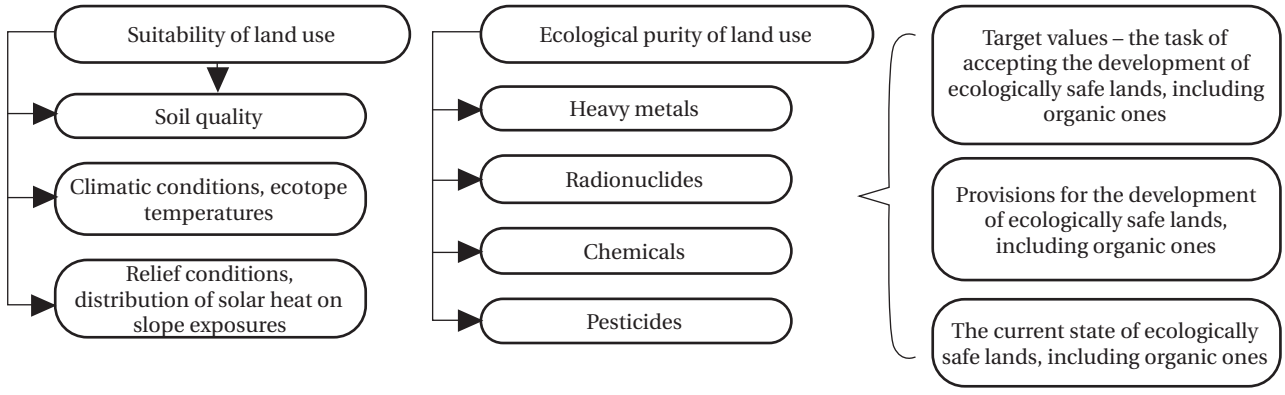

Figure 7. Scheme of development of ecologically safe (organic) lands about target values, provisions and current state of land use

Source: Based on (Tiutiunnyk, & Kupinets, 2020, p. 140)

Evidently, most of the actual data cannot satisfy the requirements of the target plan. Therefore, the optimisation of economic benefits for the farmer (community, state), with current opportunities, is to adjust investment flows about the innovative component, through which it allows bringing land use to the required level (Fig. 8).

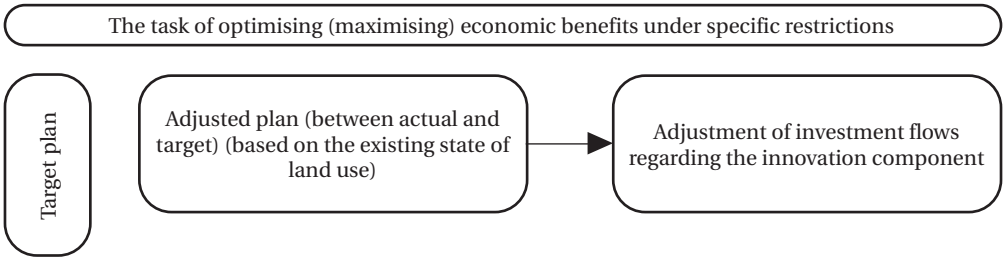

Figure 8. Diagram of the relationship between the target and existing land use plans
Source: author's development

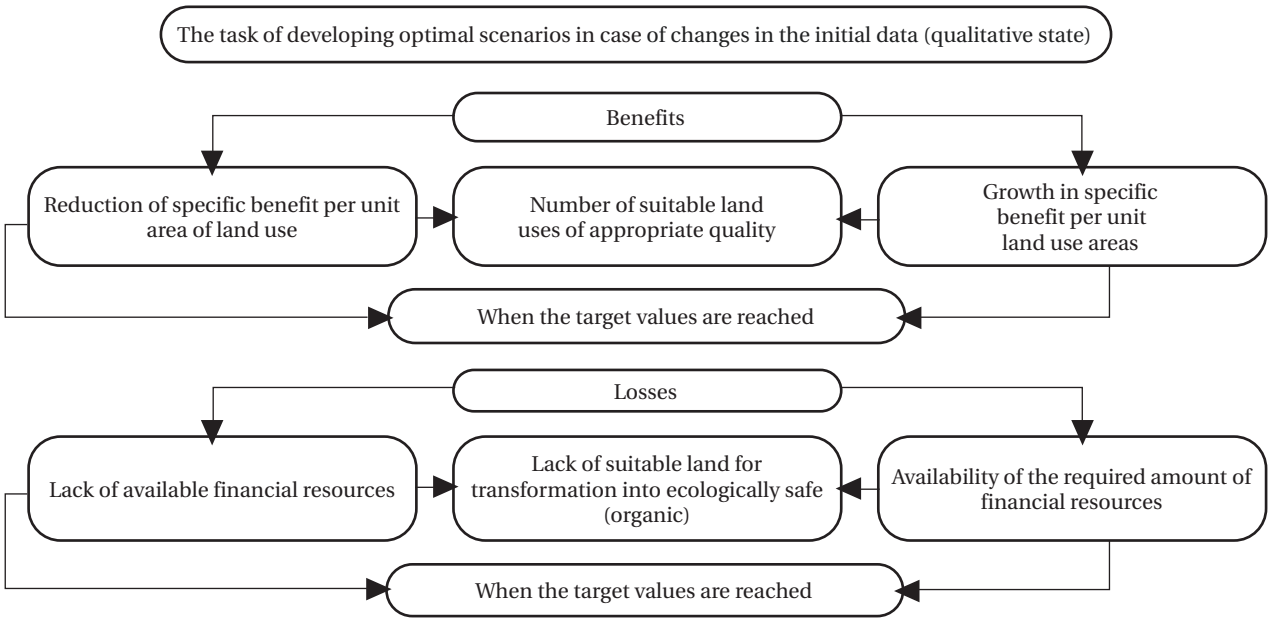

Figure 9. Benefits and losses with an appropriate amount of quality ecologically suitable land use

Deviation of plans is determined by a decrease in the specific benefit from the development of environmentally sound land use. Due to insufficient data, it is difficult to determine the exact value of benefits and costs when solving the problem of achieving the target values of environmentally sound land use.

The benefits for each community (oblast) include consideration of the deviation and conformity of the benefits in achieving the target values according to the respective availability of suitable land for transformation into environmentally safe ones. The losses are conditioned upon the lack of financial resources as a result of the transformation of suitable lands into environmentally safe ones. The result of solving the problem of developing optimal scenarios in case of changes in primary data (qualitative condition) is socio-ecological and economic improvements.

Economic improvement is the ratio of the sum of benefits from using the land and the costs of maintaining the land (the effect of improved product quality). Environmental improvement is the ratio of the sum of monetary estimates of environmental benefits to the sum of monetary estimates of environmental costs, compensations, and fines. Social improvement is the ratio of the sum of monetary estimates of employment gains to the sum of monetary estimates of employment development costs (Fig. 10).

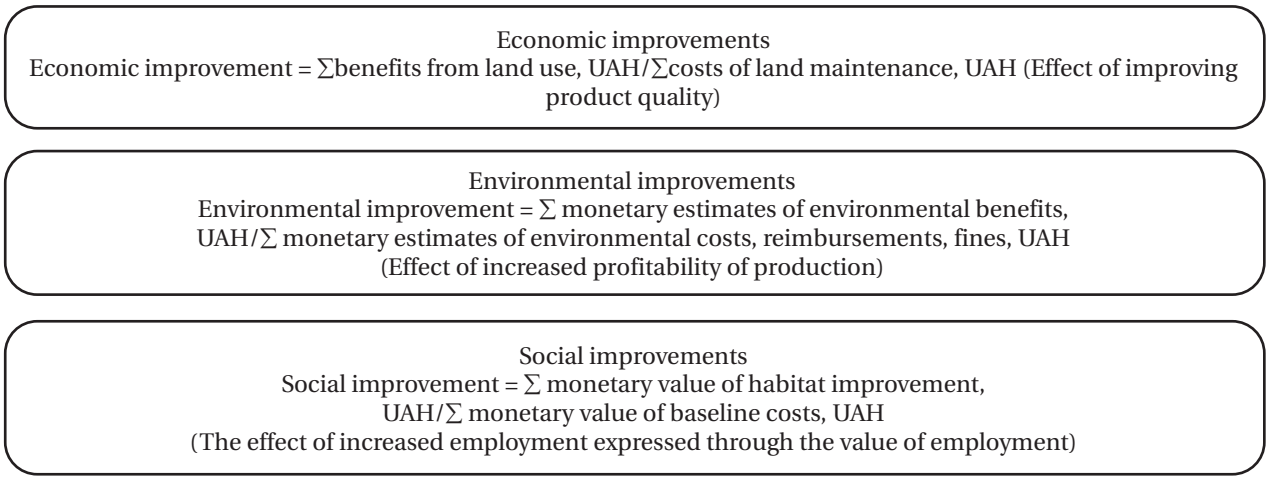

Figure 10. Socio-ecological and economic improvements to establish ecologically safe lands
Source: Author's development

where the sum of benefits from land use – expected income from production, UAH/ha; the sum of costs of land maintenance – production costs, UAH/ha; the sum of monetary estimates of environmental benefits – producer's profit from obtaining products from an ecologically clean area; the sum of monetary estimates of environmental costs, compensations, fines – producer's costs calculated for the total area of the plot; the sum of monetary estimates of habitat improvement – costs of establishing additional employment; the sum of monetary estimates of base costs – base costs for existing employment. It requires each local authority to decide on the organisation of activities to obtain benefits and prevent significant losses and risks. The target process is to identify and justify the difference between the benefits and costs of the restriction:

- availability of environmentally safe land uses;
- the most suitable land uses for transformation into environmentally safe ones;
- deficit of environmentally safe (clean) land uses.

According to the target indicators of sustainable development, the total area of ecologically safe land, in particular, organic land, should be expanded, and costs should be optimised. It will allow farmers (local authority, regions) to maintain the ecological state of land use without incurring losses and reducing motivation. The scenarios are considered as follows:

Scenario 1. Current conditions support the target values. The plan is being implemented.

Scenario 2. Existing conditions are lower than or equal to ≤10% of the target values, which is ≥90% of the current level. The plan is being implemented through several activities.

Scenario 3. Existing conditions are 20-30% lower, which is 70-80% of the current target level. This scenario means that the overall land use requires adjustments.

Scenario 4. Existing conditions are ≥30% below, which is ≤70% of the current target level. This scenario appears to be a case where significant improvements are required.

Optimal solutions may involve a trade-off between economic benefits and predetermined targets. In addition, it specifies the effects of marginal utility between the specific benefit and the amount of environmentally safe land. The obtained solutions are given in the form of determined or interval values. As a rule, solutions expressed as intervals demonstrate sensitivity to uncertainties in the model. Interval solutions can provide a range of options within a changing range of risks of loss of economic benefits.

Expected economic benefits as a result of spacing can fluctuate in a specific range and result in the establishment of alternative solutions. As the limits approach the lower limits, fewer benefits may be obtained for the ecologically oriented agricultural land use system. Therewith, when the lack of suitable land is low, it corresponds to a lower transition risk.

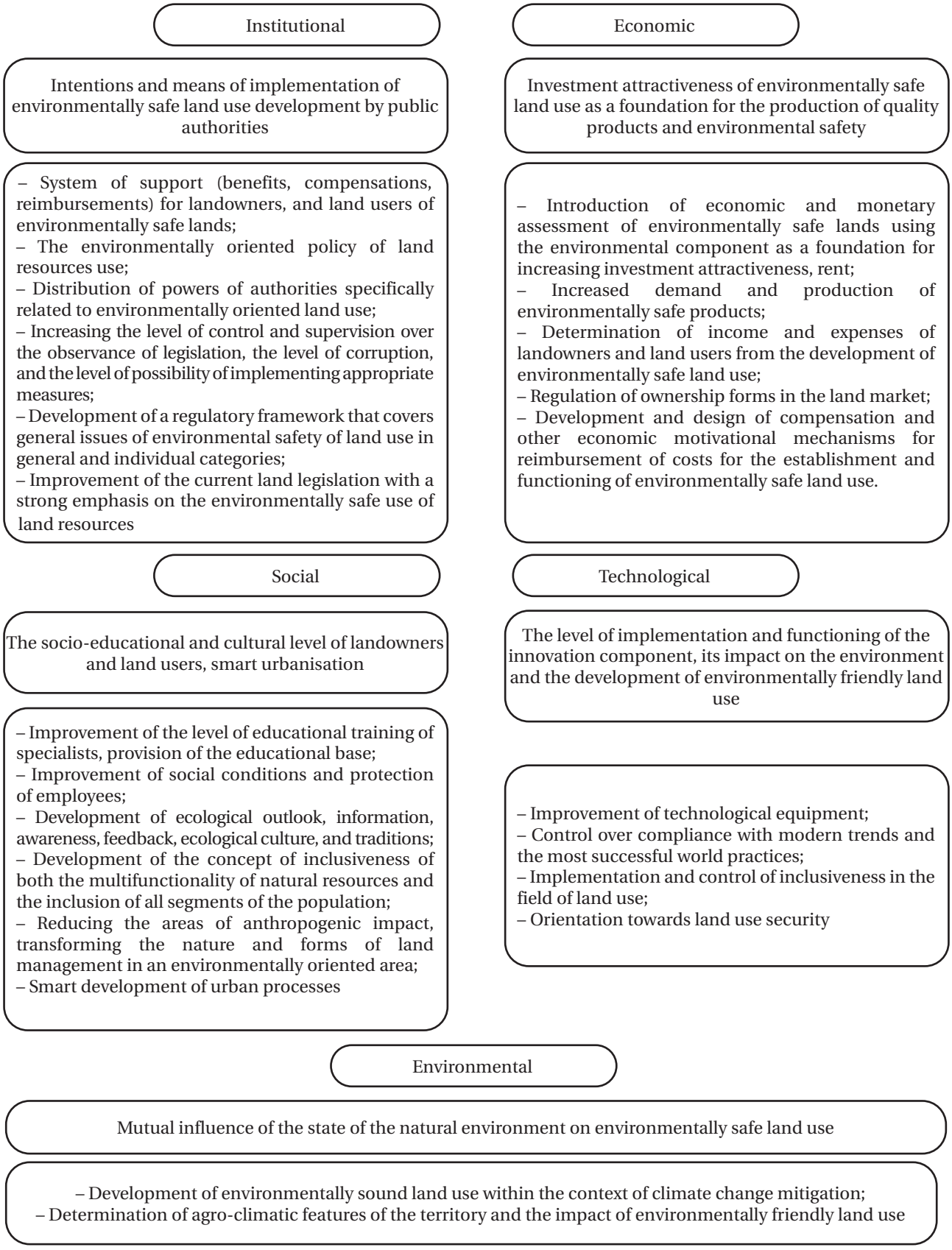

Figure 11. Strategic vectors of agrarian land use management in the context of a non-linear approach
Source: Author's development using (Tiutiunnyk, & Kupinets, 2020)

Otherwise, when the requirements for the availability of ecologically oriented land use are satisfied, higher benefits for agricultural land use can be obtained. However, the level of adverse factors may increase and increase the risk of system disruption. Thus, the results are capable of reflecting the relationship between the target values in the number of ecologically oriented land use areas, economic benefits and risk levels.

Strategic management should be implemented through the measures, plans and mechanisms of regional development strategies in which they are prescribed. Such measures should be included in the "Procedure for the development of regional development strategies and action plans for their implementation, and monitoring and evaluation of the implementation efficiency of these regional strategies and action plans". It includes vectors and required measures for the development and management of agrarian ecologically safe land use (Fig. 11).

Considering the above, the areas of strategic management of agrarian land use in the context of a non-linear approach are as follows: improvement of the current regulations (including regional programmes) on the environmentally safe use of land, their establishment, development and functioning; development of a land quality management system as part of monitoring, zoning and information and communication platform to ensure compliance of soil quality with the established standards of Ukraine and the EU, continuous monitoring and management of state authorities; development of a detailed cadastral database and cartographic representation, including innovation, investment and environmental components; training and raising the level of scientific and educational sphere, innovation provision of the scientific sphere of nature management, in particular environmentally sound land use, international cooperation; development of motivational mechanisms for environmentally sound use and valuation of land, transition to environmentally oriented management, considering the environmental component.

The expected results of strategic management of agrarian land use will be: research, control and improvement of soil quality characteristics (bio-productivity, humus establishment), improvement of biodiversity, groundwater; control and management of non-linear transformations in the system of land use; development of educational, innovative and research sphere in the field of practical use, the introduction of innovative methods of organising land use and their development, improvement of the information component for scientific research; improvement of operational control and management of agrarian land use by authorities, landowners and land users; increasing the competitiveness of the country as an exporter of environmentally friendly products and services, generating income, increasing investment attractiveness.

▸ Conclusions

It is substantiated that agricultural land use should be considered from the standpoint of nonlinearity, and all aspects of this type of system should be considered in further decisions, which will result in different economic benefits and levels of risk or development of land use. From here:

1. A scientific approach to strategic land use management in the context of nonlinear changes based on the study of qualitative and quantitative features of soil processes, possible risks, modelling and definition of scenarios for the development of strategy is proposed.

2. The algorithm of the model of nonlinear two-stage agrarian land use management under uncertainty is based on:

- approach to the development of environmentally safe lands in terms of target values, provisions and the existing state of land use;
- approach to the relationship between the target plan and the existing land use plan;
- approach to the benefits and costs of achieving target values with an appropriate amount of quality environmentally suitable land uses.

3.The strategic vectors and areas, the expected results of agrarian land use management in the context of a non-linear approach, namely the improvement of soil quality characteristics, management of non-linear transformations in the land use system, the development of the scientific and educational sphere, the improvement of the information component for scientific research, the improvement of

operational control and management of agrarian land use, the increase of the country's competitiveness as an exporter of environmentally friendly products and services are determined.

References

[1] Aljanabi, A.A, Mays, L.W., & Fox, P. (2018). Optimization Model for Agricultural Reclaimed Water Allocation Using Mixed-Integer Nonlinear Programming. *Water*, 10(10), Article number 1291. doi: 10.3390/w10101291.

[2] Cai, Y., Judd, K.L. & Steinbuks, J. (2016). A nonlinear certainty equivalent approximation method for dynamic stochastic problems forthcoming in Quantitative Economics. *Quantitative Economics,* 9(3), 118-143.

[3] Millennium Ecosystem Assessment (Program). (2005). *Ecosystems and human welfare*. Washington: Island Press.

[4] Organic crop area by agricultural production methods and crops. (2012). Data browser. Retrieved from https://ec.europa.eu/eurostat/databrowser/view/org_cropar/default/table?lang=en.

[5] Wu Zhe, Zhang Junfeng, Zhang Zhihao, Albalawi Fahad, Durand Helen, Mahmood Maaz, Mhaskar Prashant & Christofides Panagiotis. (2018). Economic Model Predictive Control of Stochastic Nonlinear Systems. *AIChE Journal*, 64, doi: 10.1002/aic.16167.

[6] Zaburanna, L., Nedilska, L., Abramova, I., Kurovska, N., & Martynuk, G. (2020). The development of the banking system in conditions of destructive impact of internal and external factors. *Scientific Horizons,* 3(88), 7-18. doi: 10.33249/2663-2144-2020-88-3-7-18

[7] Zhang, C., Yue, Q., & Guo, P.A (2019). Nonlinear Inexact Two-Stage Management Model for Agricultural Water Allocation under Uncertainty Based on the Heihe River Water Diversion Plan. *International journal of environmental research and public health*, 16(11). Article number 1884. doi: 10.3390/ijerph16111884.

[8] Institute of Soil Protection of Ukraine. (n.d.). *Agrochemical survey of agricultural lands*. Retrieved from http://www.iogu.gov.ua/pasportizaciya/ahro-himichne-obstezhennya-silskohospodarskyh-uhid/.

[9] Hutorov, A.O. (2009). Determining the optimal size of land use of agricultural enterprises. *Economika APK*, 4, 55-62.

[10] Kubakh, P. (2021). The impact of the shadow market on the development of agriculture and rural areas. *Voks Ukraina*. Retrieved from https://voxukraine.org/vplyv-tinovogo-rynku-na-rozvytok-silskogo-gospodarstva-ta-silskyh-terytorij/.

[11] Kuznetsov, A.V. (1994). *Mathematical programming*. Mykolaiv: Vyshcha shkola.

[12] Nakonechnyi, S.I., & Savina, S.S. (2003). *Mathematical programming*. Kyiv: KNEU.

[13] Ministry of Ecology and Natural Resources of Ukraine. (2020). *National report on the state of the environment in Ukraine in 2019*. Kyiv: FOP Hrin D.S.

[14] National report on the state of soil fertility of Ukraine. (2010). Kyiv. «VYK PRINT» LLC.

[15] Federation of Organic Movement in Ukraine (n.d.). Organic in Ukraine. Retrieved from http://organic.com.ua/organic-v-ukraini/.

[16] Organic production in Ukraine. Informational and analytical portal APK. (2021). Retrieved from https://agro.me.gov.ua/ua/napryamki/organichne-virobnic-tvo/organichne-virobnictvo-v-ukrayini.

[17] List of regional target programs operating in the region as of May 1, 2021. (2021). Retrieved from http://khor.gov.ua/regionalni-tsilovi-programy/.

[18] Periodic report on the state of soils. Retrieved from http://www.iogu.gov.ua/publikaciji/stan-gruntiv/.

[19] Potockaja, N.S. (2017). Ecological and economic system: Methodological approaches to management. Strategy and tactics of development of production and economic systems. Gomel': GGTU im. P.O. Suhogo.

[20] Law of Ukraine № 1264-XII "On environmental protection". (2021, January). Retrieved from: https://zakon.rada.gov.ua/laws/show/1264-12#Text.

[21] Resolution of the Cabinet of Ministers of Ukraine No. 621 "On the development of forecast and program documents of economic and social development and drafting of the Budget Declaration and the state budget". (2003, April). Retrieved from https://zakon.rada.gov.ua/laws/show/621-2003-p#n260.

[22] Soloviov, A.I. (2015). *Infocommunication support of management of agrarian production structures.* Kherson: Hrin D.S.

[23] Tiutiunnyk, H.O., & Kupinets, L.Ye. (2020). Concentration of ecologically safe agricultural lands: Economic and organizational support. Odesa: IPREED NANU.

[24] Khlivna, I.V. (2013). Economic and mathematical problems of agricultural optimization as increasing employment in rural areas. *Ekonomika ta Derzhava*, 7, 37-39.

[25] Ministry of Economic Development and Trade of Ukraine. (2017). *Sustainable Development Goals: Ukraine. National report.* Retrieved from http://surl.li/eljaj

Управління аграрним землекористуванням у контексті нелінійного підходу

Лариса Євгенівна Купінець, Ганна Олексіївна Тютюнник

Державна установа «Інститут ринку і економіко-екологічних досліджень НАН України»
65000, Французький бульвар, 29, м. Одеса, Україна

Анотація. Використання земельних ресурсів не відповідає вимогам врівноваженого природокористування. Значна частина земель через надмірну розораність, інтенсивні процеси деградації втратила економічну родючість. Екологічний стан залучених у сільськогосподарське використання земель настільки погіршився, що тепер, оскільки земельні ресурси в агробізнесі виступають як засіб виробництва, від них залежить економічний стан господарюючих суб›єктів, так і продовольча безпека країни. Мета статті – розвинути наукове бачення стратегічного управління землекористуванням у контексті нелінійних змін на засадах дослідження якісних і кількісних ознак ґрунтових процесів, можливих ризиків та моделювання сценаріїв розвитку. Використано сукупність методів, принципів і прийомів наукового пізнання: статистичний аналіз – при характеристиці довгострокових регіональних цільових програм щодо охорони та раціонального землекористування (екологічно безпечного) на прикладі Причорноморського регіону; порівняльний аналіз – при визначенні рівня забезпеченості регіонів України екологічно безпечними землями, стану довкілля в зоні екологічно безпечного землекористування, забезпеченості екологічними територіями і придатними до трансформації, порівнянні цільових значень площ аграрних землекористувань під органічним виробництвом; графічний – для наочного відображення моделі нелінійного двоетапного управління аграрним землекористуванням в умовах невизначеності її складових. Запропоновано: шляхи формування екологічно безпечних земель (органічних) щодо цільових значень, норми і стану землекористування; взаємозв›язок планів цільового та наявного стану землекористування; облік вигід і втрат досягнення цільових значень за відповідної кількості екологічно придатних землекористувань. Визначено стратегічні вектори, напрями та очікувані результати управління аграрним землекористуванням у контексті нелінійного підходу. Наукова новизна дослідження полягає в обґрунтованому алгоритмі моделі нелінійного двоетапного управління аграрним землекористуванням в умовах невизначеності. Обґрунтовано прорахунки державного управління земельними ресурсами як передумови стратегічного управління аграрним землекористуванням. Представлено модель нелінійного двоетапного управління аграрним землекористуванням в умовах невизначеності. Розроблено стратегічні вектори управління аграрним землекористуванням у контексті нелінійного підходу

Ключові слова: стратегічне управління, нелінійність, стратегування, цілі сталого розвитку, моделювання