frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 29 October 2024
DOI 10.3389/fenvs.2024.1446056

OPEN ACCESS

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RECEIVED 08 June 2024
ACCEPTED 17 October 2024
PUBLISHED 29 October 2024

CITATION
Saik P, Koshkalda I, Bezuhla L, Stoiko N and Riasnianska A (2024) Achieving land degradation neutrality: land-use planning and ecosystem approach.
Front. Environ. Sci. 12:1446056.
doi: 10.3389/fenvs.2024.1446056

Achieving land degradation neutrality: land-use planning and ecosystem approach

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Introduction: The research purpose is to scientifically substantiate an integrated approach to solving the problem of land degradation, based on the idea of land degradation neutrality (LDN), taking into account ecosystem services when planning land use to maximize the conservation of natural capital. The methodological basis of the research is the provisions and principles of the concepts of sustainable development, achieving LDN, and ecosystem services, as well as the research results revealing various aspects of land use, particularly their degradation.

Methods: The following research methods are used in the paper: dialectical – to determine the cause-and-effect conditions of land degradation; analysis – to highlight the current state of land use in Ukraine and the factors that have led to land degradation; synthesis – for global trends towards achieving LDN; deduction – to explore the possibility of introducing global experience in achieving LDN in Ukraine; structural-functional analysis – to substantiate the feasibility of introducing an ecosystem approach to land-use planning to achieve LDN.

Results: As a result of the research, the current land degradation state in Ukraine has been analyzed, and ways of achieving LDN in land-use planning through the prism of an ecosystem approach have been substantiated. Based on statistical data, the current and potential levels of arability of the territory of Ukraine have been calculated by natural-climatic zones, and the areas of eroded arable lands in Ukraine have been determined by the erodibility factor (low-eroded, mediumeroded,and highly-eroded).

Discussion: For the first time, a structural-logical scheme has been developed for organizational-economic support for the effective use of degraded and low-productive agricultural lands in the context of implementing the idea of LDN, which is a tool for rational allocation and use of degraded lands. This scheme can serve as a basis for the development of land-use planning strategies for territorial communities, for institutions, and organizations competent in the field of land management.

KEYWORDS

land degradation neutrality, ecosystem approach, land-use planning, land erosion, erodibility factor, natural-climatic zones

1 Introduction

According to the data of Convention to Combat Desertification and the Intergovernmental Working Group report on LDN estimate that water erosion has damaged over 24% of land; wind erosion – over 12%; chemical degradation – up to 6%; physical degradation – up to 2% of the globe's agricultural land. Analysis of Ukrainian and international reports, as well as other data provided by the United Nations Convention to Combat Desertification (UNCCD), has shown that in 2019 approximately 20% of the globe's land cover is degraded to some extent (almost 30 million km^2, which is an area the size of the African continent) (UNCCD, 2015). The concept of LDN is implemented within the framework of the United Nations Convention to Combat Desertification. The strategic goal of the concept is to maintain the productivity of land resources to provide essential ecosystem functions and services, as well as to improve food security today and in the future (Wang et al., 2022).

LDN objectives are interrelated with the concept of ecosystem services, pointing to the interdependence between human well-being and ecosystem sustainability. At the same time, the sustainability of ecosystems depends on the extent of their biodiversity, the loss of which has a negative impact on the production of vital services provided by ecosystems. A decline in the quality of ecosystem services results in significant economic losses and healthcare costs (Yuan et al., 2022; Makarova et al., 2023; Li et al., 2023; Zhang et al., 2022).

More than 3 billion people in the world, mostly poor rural communities, smallholder farmers and high-risk groups, have already been affected in one way or another by various types of land degradation. The situation is particularly acute in arid regions, which account for more than 45% of the total land area, and today one in three people in the world live in such regions. Land degradation – the permanent reduction or loss of soil fertility – has a significant impact on society and, in particular, leads to poverty, hunger, inequality, which in turn makes communities vulnerable to disease and disasters. At the same time, desertification, expansion of arable lands, and their urbanization are causing significant losses of organic carbon reserves in the soil, leading to a steady decline in the productivity of all ecosystems, with pastures experiencing the greatest losses of productivity, carbon, or land itself (Koshkalda et al., 2018; Sheludko et al., 2022; Koshkalda et al., 2022a).

Land degradation and excessive anthropogenic pressure have altered biodiversity that underpins the provision of ecosystem services sustaining life on Earth (Mulwafu and Kamchedzera, 2024; Kostenko et al., 2023; Du et al., 2024). This means that these changes threaten the survival of many species. Global warming has altered the geographic distribution, seasonal dynamics, and population characteristics of many plants and animals (Price et al., 2024; Koval et al., 2023). Endangered and extinct species pose a threat to the normal functioning of ecosystems. Thus, a globally accepted indicator – the Living Planet Index – shows that in the period from 1970 to 2016, the decline in populations of mammals, birds, fish, etc., averaged 68%. In tropical America, for example, this rate has declined by 94%, mainly due to land-use change (primarily the conversion of grasslands, savannas, forests and wetlands for agriculture and mining), indicating the need for land-use planning to achieve LDN. As for Ukrainian realities, the soil organic carbon content in Ukrainian chernozems has reached extremely low values, leading in subsequent years to degradation of agrophysical properties, which inevitably leads to the loss of arable land as a natural resource potential component (Stoiko and Parsova, 2017; Singh and Tewari, 2022; Haj-Amor et al., 2022; Schulze et al., 2021; Bär et al., 2023; Koshkalda et al., 2022b).

Today, the field of research into LDN has evolved from the drylands of Africa and Asia to a global scale of environmental rehabilitation of degraded lands in all regions of the world (Tóth et al., 2018; Gilbey et al., 2019).

Achieving land degradation neutrality requires the implementation of measures in compliance with the "Avoid – Reduce – Reverse" land hierarchy and is based on the principle "it is better to prevent degradation than to rehabilitate degraded lands." Three global indicators are used to assess land degradation neutrality: land cover, land productivity, and soil carbon content.

Achieving LDN requires the implementation of measures in compliance with the Avoid – Reduce – Reverse land hierarchy and is based on the principle "it is better to prevent degradation than to rehabilitate degraded lands." The potential socio-economic and environmental benefits of LDN indicate the feasibility of adapting this concept at the national, regional and local levels by integrating it into development planning processes, financing environmental protection, and informing policymakers and the public about the goals of LDN to stimulate investment (Allen et al., 2020; Dwivedi et al., 2022; Chigbu et al., 2022).

To achieve the goals of LDN, sustainable land management (SLM) practices are important, allowing for the implementation of measures to protect agricultural lands from degradation and measures to restore degraded lands through rehabilitation, renaturalization, and reclamation (Chigbu et al., 2022; Zucca et al., 2024). SLM measures are implemented at the landscape level through integrated land-use planning, while results are assessed at the regional and state levels (Alpysbay and Gapparov, 2021; Cowie et al., 2019).

Realizing the importance of land resources in the context of implementing the Sustainable Development Goals by 2030, there is a need to focus attention and efforts on the issue of land degradation (LDN; Target 15.3) in SDG15 ("Life on land") by combating desertification, rehabilitating degraded lands, and achieving their globally neutral level of degradation (UNDP, 2019; FAO, 2021). Furthermore, achieving LDN is intertwined with other global land-related Sustainable Development Goals, such as "Zero Hunger" (SDG 2), "Clean Water and Sanitation" (SDG 6), and "Climate Action" (SDG 13), corresponding to provisioning and regulating services (UNCCD, 2017; UNCCD, 2019; UNDP, 2019).

The international community has announced plans to rehabilitate 1 billion hectares of degraded land by 2030. The stated goal is to conserve natural ecosystem life-support services and land productivity for future generations, while reducing the risks and consequences of natural disasters and pandemics, and increasing ecosystem and societal resilience to impending environmental stresses and climate shocks.

Today, almost a third of Europe's arable land is concentrated in the territory of Ukraine, which prompted the authors to choose this country as the research object (Kovalchuk, 2022; Petrakovska et al., 2022; Petrakovska et al., 2020; Trehub and Trehub, 2018; Trehub and Trehub, 2017; Stoiko et al., 2023; Stoiko, 2020). According to various estimates and approaches, Ukraine has from 8 million to 15 million hectares of degraded land, including up to 13 million hectares damaged by water erosion, and more than 6 million hectares affected by wind erosion, while dust storms have covered up to 20 million hectares of agricultural land. Today, Ukraine's priority environmental policy is to ensure the sustainable use and protection of land, improve the condition of affected ecosystems, promote achieving a neutral level of land degradation, and raise awareness among the population, landowners, and land users regarding land degradation issues (The Law Of Ukraine, 2019; Verkhovna Rada of Ukraine, 2019).

Achieving LDN will ensure the rehabilitation of not only land, but also ecosystems, which in turn will very slightly enhance climate change mitigation. Additionally, the importance of the ecosystem approach stems from the need to restore biodiversity habitats to avoid extinction and to restore the unimpeded movement of species and the natural processes that sustain life on Earth. Thus, research and the formulation of ecosystem approach principles in land-use planning in Ukraine are promising ways to achieve LDN, ensure sustainable development, and conserve natural resources for future generations (Burkovskiy, 2022; Pogrischuk, 2017; DeClerck et al., 2023; Robinson et al., 2022; Hillebrand et al., 2017).

The research purpose is to scientifically substantiate an integrated approach to solving the problem of land degradation in Ukraine, based on the idea of LDN, while considering ecosystem services in planning land use to maximize the conservation of natural capital. To achieve this purpose, this paper analyzes the natural-climatic zones of Ukraine, establishes the level of arability of the territory, and determines the project level of arability based on the Environmental Noncompliance Index of current cultivated lands. Furthermore, considering aspects related to the conservation of arable land or its conversion to other types of economic activities, a scheme for organizational-economic support for the effective use of degraded and low-productive agricultural lands in the context of implementing the idea of LDN has been developed.

Land-use planning is a tool for managing land resources that has been utilized since ancient times to protect land and people from natural disasters, as well as to address important issues related to land use, with the aim of ensuring the sustainability of land systems (Meyer and Turner, 1994; Bazaluk et al., 2024; Burby, 1998).

Considering the diverse suitability of land resources for different types of activities, the natural constraints on the placement of objects, and competition for the same resources, the primary objective of land-use planning is to optimize the choice of land-use methods and types of activities that ensure the most effective use of land resources in terms of socio-economic benefits and minimizing ecological harm, resolving land-use conflicts, reducing negative impacts, and achieving environmentally and socially beneficial outcomes, as well as ensuring a fair distribution of costs and benefits among all stakeholders (Godschalk, 2004; Randolph, 2004).

2 Materials and methods

2.1 Study area

Ukraine is a country in Central-Eastern Europe with an area of 603,628 km^2. According to Boris Alisov's classification, the territory of Ukraine has only two types of climate: temperate-continental climate almost throughout the entire territory and a Mediterranean climate on the Southern Coast of Crimea (Shimabukuro et al., 2022). The general pattern of Ukraine's climate is an increase in its continentality from west to east and a close to latitudinal zonation in the distribution of temperature, humidity, and precipitation. This is due to the contrasting distances of the western and eastern regions from the Atlantic Ocean. The average annual temperature is 6°C–7°C above zero in the north and 12°C–13°C above zero in the south. The coldest area is the northeastern part of Ukraine, while the warmest is the southwestern and Southern Coast of Crimea. Precipitation is unevenly distributed over the territory of Ukraine. Rainfall depends on the season, topography, geographical location of the area, and other factors. The most precipitation falls in the mountainous regions of the Carpathians (in some areas over 1,500 mm), and the least on the coasts of the Black and Azov Seas (about 300–350 mm) (Maps of Ukraine, 2024).

According to natural-climatic zones, Ukraine is divided into three zones: forested lowland, forest-steppe zone, and steppe. To ensure effective land management, natural-climatic zones are adjusted taking into account the administrative-territorial arrangement, which includes 24 oblasts and Crimea. Thus, the forested lowland zone includes 7 oblasts of Ukraine, the forest-steppe includes 9 oblasts, and the steppe includes 8 oblasts and Crimea.

Normal precipitation in the forested lowland zone is 550–700 mm/year, and in the forest-steppe, it is 600–450 mm/year. In the forested lowland and forest-steppe, there is a gradual decrease in precipitation from west to east. In the northern areas of the steppe zone, there is precipitation of 450–475 mm/year, while the lowest precipitation (300–350 mm/year) falls in the southern sea coast lowland areas. In the steppe zone of Crimea, the amount of precipitation increases southward towards the Crimean Mountains (up to 470–500 mm/year). More than 1,000 mm/year of precipitation falls in the Crimean Mountains and 550–600 mm/year on the Southern Coast of Crimea. In the warm season, precipitation is 2–3 times more than in the cold season. An exception is the Southern Coast of Crimea, where the greatest amount of precipitation occurs during the cold season (RCCC Country profiles Ukraine, 2024).

The following soils are common within Ukrainian Polissia: soddy-podzolic, soddy-podzolic gley, soddy-calcareous, soddy gley, soddy-meadow, marshy, gray forest, and podzolized chernozem soils. The term "soddy" refers to soils that have a sod-like layer formed by the accumulation of organic matter on the surface, often found in regions with a significant amount of vegetation and moisture, such as Podzol-Histosol-Gleysol soils, and is commonly associated with Leptosols or Cryosols. This diversity of soil cover is caused by a humid and mild climate, a wide variety of chemical and mineral composition, well-developed meso- and micro-relief, close and very uneven groundwater occurrence, a variety of plant formations, and different intensities of human economic activity.

The soil cover of the forest-steppe zone is dominated by various types of chernozems (typical and podzolized) and gray forest soils formed on loess or loess-like loams. In the lowlands, meadow and meadow-chernozem soils are common, with peat soils in some places. Soil fertility levels are highest in the middle and eastern parts of the zone. The southern border of the forest-steppe zone almost coincides with the transition from typical chernozems, which are richer in organic matter and more fertile, to leached chernozems, which have slightly less organic content and fertility. An important natural resource of the steppe zone is its fertile soils, primarily chernozems. The zone ranks first in Ukraine in terms of the area of chernozems. It is the northern distribution of thick leached chernozems that is taken as the border separating the forest-steppe and steppe zones. Significant areas are occupied by very deep (over 120 cm), deep (80–120 cm) and medium-deep (60–80 cm) chernozems. Their soil organic carbon content ranges from 3% to 6%. Such highly productive chernozems account for more than 90% of all chernozem soils here (Maps of Ukraine, 2024; RCCC Country profiles Ukraine, 2024).

Soils of the steppe zone have significant territorial differences. While typical chernozems are widespread in the far north, leached chernozems are widespread in the central part, and dark chernozems are found in the southern regions. Chestnut soils are widespread in Prysyvashsha and Northern Crimea, while dark chernozems and soddy soils are widespread in the western and foothill parts of Crimea.

The soil organic carbon content in Ukrainian chernozems has reached extremely low values, leading to degradation of agrophysical properties and resulting in the loss of arable land as a natural resource.

According to various estimates and approaches, Ukraine has between 8 and 15 million hectares of degraded land, of which more than 1.1 million hectares need conservation, 0.315 hectares are low-productive lands, and 0.143 hectares require reclamation (Shimabukuro et al., 2022).

2.2 Methods

The methodological basis of the research includes the provisions and principles of concepts such as sustainable development, achieving LDN, and ecosystem services. The research results reveal various aspects of land use, particularly their degradation. The cause-effect conditions of land degradation, as well as the current state of land use in Ukraine and factors leading to land degradation, have been identified using the dialectical method. Global trends towards LDN are highlighted through the synthesis method.

Three global indicators are used to assess LDN: land cover, land productivity, and soil carbon content. These indicators reflect the land's ability to provide ecosystem services and require extensive data for determination and analysis (Orr et al., 2017; Khazieva et al., 2023; Prăvălie et al., 2021; Cowie et al., 2018; Cowie et al., 2019; Gonzalez-Roglich et al., 2019). Most data can be obtained through a combination of indicator and questionnaire methods. The indicator method includes determining indicators such as soil erodibility, forest cover, land pollution, soil loss, and moisture content. The questionnaire method involves surveys of farmers, land users, and other stakeholders, as well as remote sensing-based mapping. However, indicators such as land productivity (Net primary productivity indicator, quantitatively described by the Normalized Difference Vegetation Index or Enhanced Vegetation Index) and organic carbon reserves in the soil are difficult to determine (Feng et al., 2022; Casas-Ledón et al., 2023; Liu et al., 2021; Cui et al., 2022; Pei et al., 2013).

Structural-functional analysis enabled the processing of data on quantitative indicators of land degradation in Ukraine and the calculation of indicators of the current and potential levels of arability of Ukraine's territory by natural-climatic zones (low-eroded, medium-eroded, and highly-eroded). The project level has been determined using the Environmental Noncompliance Index of the current use of cultivated lands, numerically expressed as the ratio of actually cultivated land plots (according to land records) to the total area of land suitable for cultivation. When calculating the project level of arability, the indicator of exceeding the permissible arability is subtracted from the actual level.

The research utilized data from the analytical report "Land policy as a key and integral element of Ukraine's environmental policy," prepared as part of the project "Increasing Transparency and Accountability in Grassland Plowing," implemented in Ukraine by the public organization "Ukrainian Nature Conservation Group" with the support of the National Fund for the Support of Democracy. This document analyzes Ukraine's situation regarding natural ecosystems as a key factor in forming and maintaining a viable environment, considering land policy as an integral component of Ukraine's environmental policy.

The concept of the article lies in the scientific justification of an integrated approach to addressing the problem of land degradation through the implementation of the idea of land degradation neutrality (LDN). The main goal is to achieve a balance between the degradation and restoration of land resources through sustainable land resource management and the application of ecosystem approaches. In this regard, it is anticipated that goals such as the conservation of natural capital, improvement of ecosystem services, and effective land-use planning to mitigate the negative impacts of erosion, urbanization, and other degradation processes will be achieved. The study emphasizes the necessity of land planning considering natural-climatic zones, introducing measures to prevent soil degradation and restore eroded lands. An important element of the concept is the use of an ecosystem approach in spatial planning to achieve sustainable development and conserve biodiversity.

3 Results and discussion

As a result of the research, it has been found that arable lands in Ukraine cover about 56% of its area (338 thousand km^2). The level of arability varies from 15% in Zakarpattia Oblast to more than 69% in Mykolayiv and Zaporizhia Oblasts. On average, the level of arability in the forested lowland zone is about 35%, in the forest-steppe zone – about 59%, and in the steppe zone – about 62%. Having examined the existing state of land use in Ukraine, the authors of the

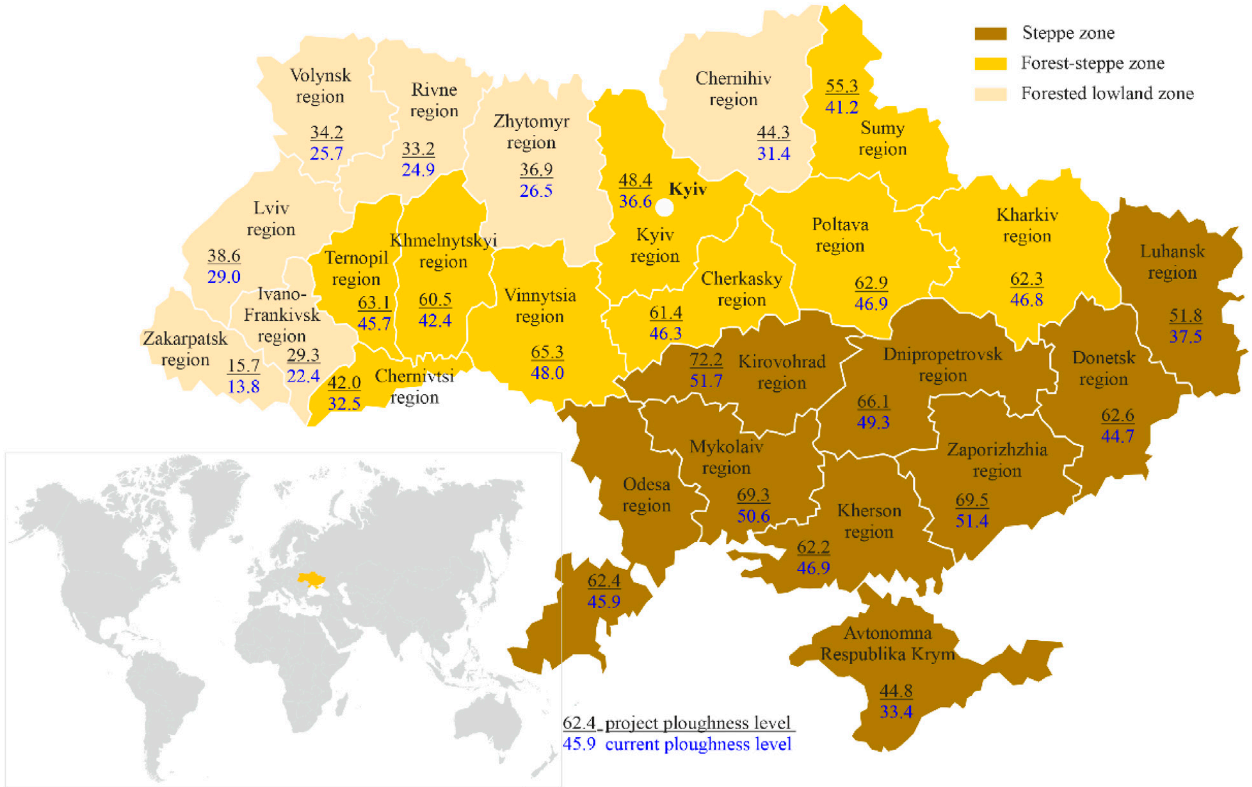

FIGURE 1
Data on the current and potential levels of arability of the territory of Ukraine according to natural-climatic zones [based on the study (Burkovskiy, 2022)].

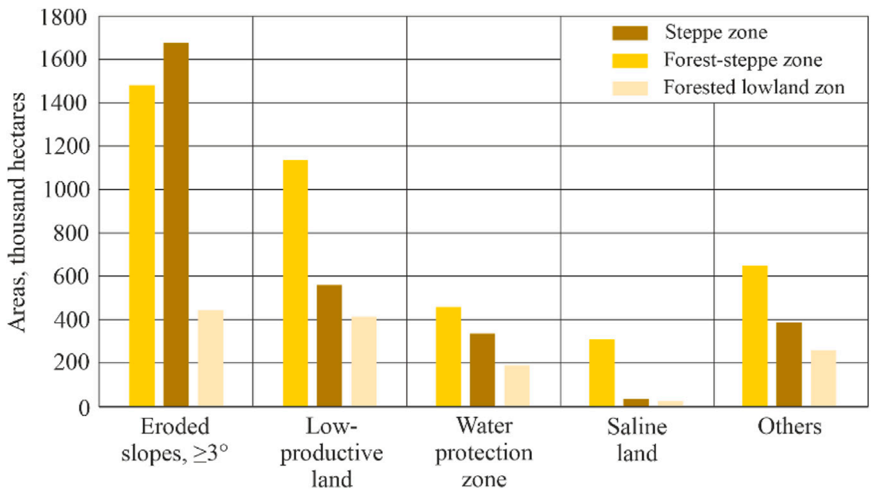

FIGURE 2
Project indicators for the conversion of arable land to natural forage grassland and afforestation [based on the study (Burkovskiy, 2022)].

work systematized and obtained data regarding the current and potential levels of arability of the territory according to natural-climatic zones (Figure 1).

The data analysis in Figure 1 indicates that the leaders among the regions of Ukraine in terms of the existing level of land arability, considering natural-climatic zones, are Chernihiv Oblast (forested lowland zone – 44.3%), Vinnytsia Oblast (forest-steppe zone – 65.3%), and Kirovohrad Oblast (steppe zone – 72.2%). The same leadership is maintained at the project arability level of 31.4%, 48.0%, and 51.7%, respectively (Burkovskiy, 2022). As

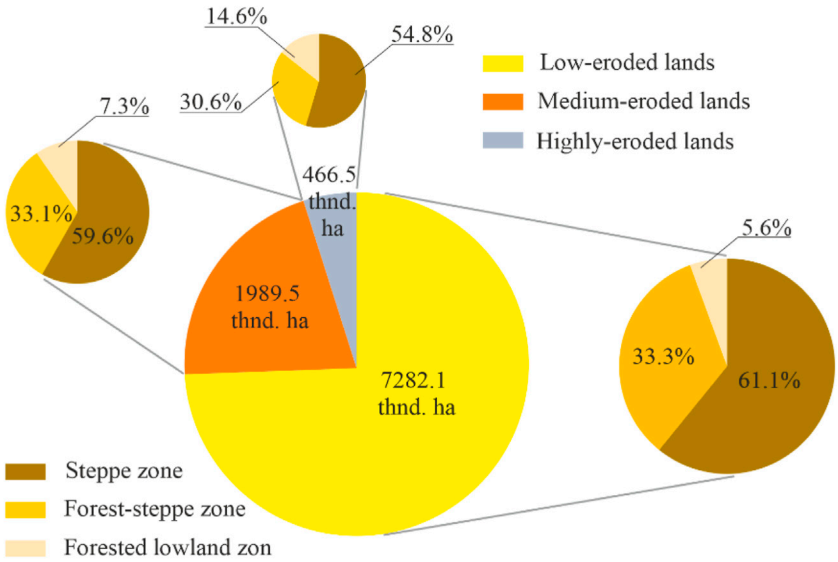

FIGURE 3
Data on the area of eroded arable land in Ukraine by natural-climatic zones [based on the study (Burkovskiy, 2022)].

indicated in the paper (Burkovskiy, 2022), to maintain the balance of Ukrainian landscapes, some arable land should be conserved or converted to other categories. This means that no agricultural work will be carried out on it; instead, a meadow or forest (depending on the climatic zone) will be established. Over time, soil quality improves, and agricultural work can be resumed here. Project indicators for the conversion of arable land, which is currently used for economic purposes and varies by natural-climatic zones, are given in Figure 2.

Analysis of the data presented in Figure 2, considering the level of arable land degradation by natural-climatic zones, shows a total of 8,629.4 thousand hectares of arable land in Ukraine that should be converted to conservation, including: 3.69 million hectares of arable land on slopes with a steepness of 3° or more; 2.18 million hectares of low-productive land where farming is economically unfeasible – material and energy costs exceed production cost; 1.04 million hectares of arable land in the drainage network; 1.56 million hectares of land located near livestock farms and around settlements for the creation of hayfields and pastures; and 50 thousand hectares of land contaminated with radionuclides and heavy metals (Burkovskiy, 2022).

At the same time, according to the Law of Ukraine "On Land Protection" (The Law of Ukraine, 2024), the following are subject to conservation:

- land plots used in violation of requirements to protect land from erosion and landslides;
- arable land with one of the indicators characterizing soil properties that necessitate land conservation by natural-agricultural zones, determined in accordance with the appendix;
- degraded lands, low-productive lands without steppe, meadow, forest vegetation cover, the economic use of which is ecologically dangerous and economically inefficient, as well as technogenically polluted land plots where it is impossible to obtain ecologically clean products, and the stay of people on these land plots is unsafe for their health;
- other degraded and low-productivity lands.

A significant part of arable land is exposed to continuous erosion processes that significantly reduce soil organic carbon content, nitrogen, phosphorus, potassium, microelements, etc. The content of organic matter in the fertile soil horizon decreases. An analysis of reference (Pogrischuk, 2017) has shown that erosion causes a significant decrease in soil organic carbon content in eroded lands. In total, about 0.7 million tons of soil organic carbon are lost due to erosion per year. Figure 3 provides information on the area of low-eroded, medium-eroded, and highly-eroded lands.

Analysis of the data given in Figure 3 shows that the largest land area belongs to low-eroded lands. In particular, the steppe zone accounts for 4,449.36 hectares, the forest-steppe zone – 2,424.94 hectares, and the forest zone – 407.79 hectares (Burkovskiy, 2022). To select effective measures to suppress soil erosion processes based on predetermined trends in their manifestation, it is necessary to analyze the cause-and-effect relationships between the type of soil erosion and the direct/non-direct causes of these erosion processes. For example, arable slopes lead to planar or linear water erosion of soils. Moreover, the intensity of erosion processes depends on factors such as the length and steepness of the slope, mechanical composition of the soil, intensity of precipitation, and agricultural practices. These erosion processes can be minimized or stopped by implementing soil protection and erosion control measures that require additional costs from land users.

In turn, failure to take these measures due to ineffective economic leverage, lack of funds, lack of awareness, or other indirect reasons leads to further soil erosion manifestation. At the same time, these slope areas can be removed from intensive cultivation for hayfields, pastures, or forest lands and used for agricultural, forestry, recreational, or nature conservation

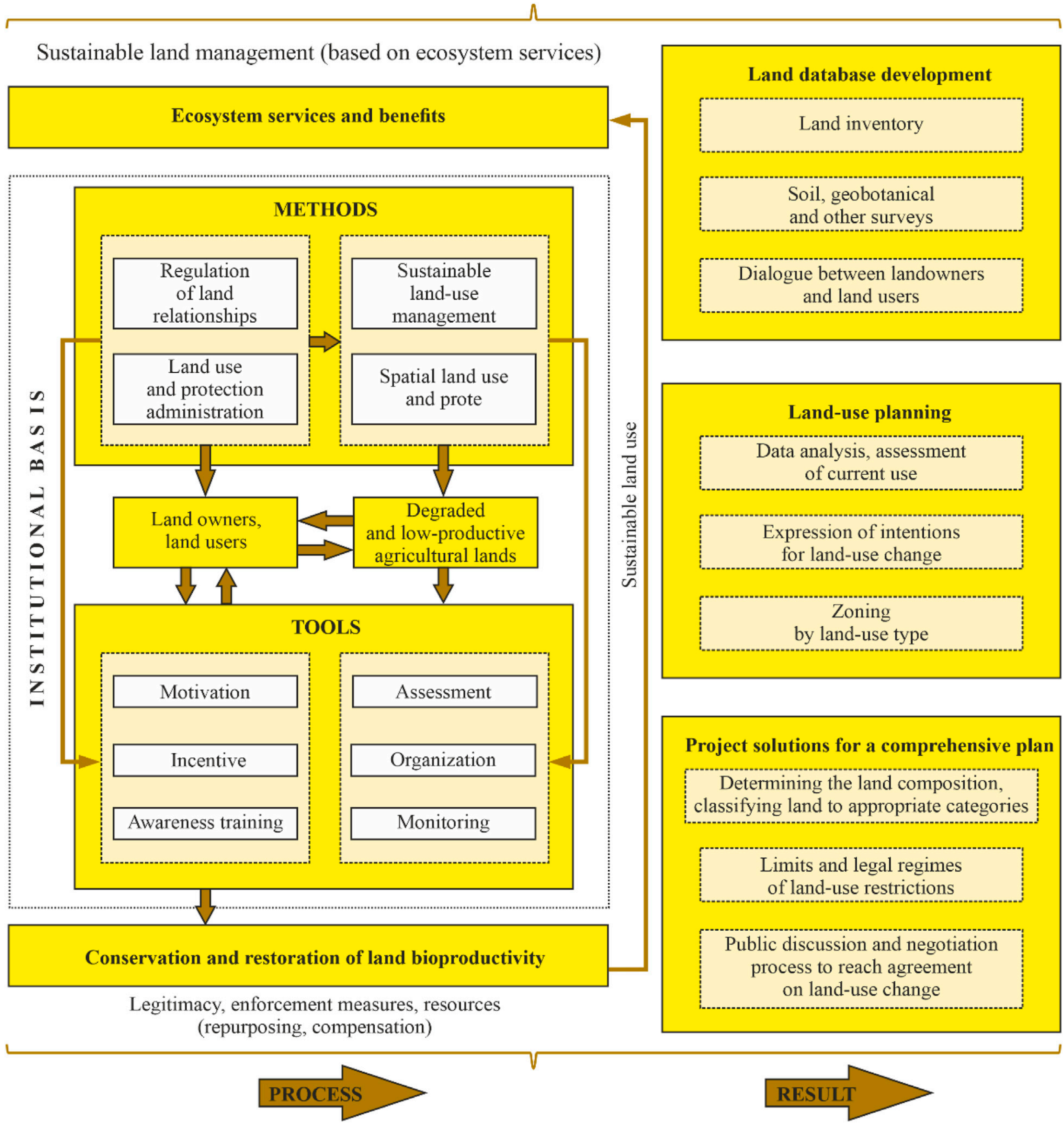

FIGURE 4
Structural-logical scheme for organizational-economic support for the effective use of degraded and low-productive agricultural land in the context of implementing the idea of LDN.

purposes. This raises the question–how to make the right decision and choose the best alternative for the use of erosion-hazardous arable land masses? And this choice is not only for the landowner or land user. Given the concept of LDN, which is primarily a political phenomenon, this decision should be envisaged in local, regional, and state policies through SLM and spatial planning.

SLM refers to a process that seeks to integrate the management of land, water, biodiversity, and other natural resources to meet human needs while supporting ecosystem services and livelihoods. Spatial planning is an important component of territorial development management and implies geographical reflection of economic, social, cultural, and environmental policies of society. The purpose of spatial planning is to order and regulate the use of land effectively to meet people's needs within a particular space.

Given the diversity of natural, social, economic, political and other conditions of territorial development, there are no specific measures to achieve LDN within these territories. On the contrary, the variability of alternatives is as varied as the different types of erosion and the extent of erosion processes, as well as the reasons for their occurrence. It is important to develop a set of measures that will include the full range of possible actions to prevent or minimize erosion processes and/or restore the quality of already eroded soils. Taking into account the above-mentioned factors, the authors of the paper have developed a scheme for organizational-economic support for the effective use of degraded and low-productive agricultural lands in the context of implementing the idea of LDN to maximize the preservation of natural capital (Figure 4).

The structural-logical scheme for organizational-economic support effectively describes the system of relationships between landowners and land users in the process of using degraded and low-productive agricultural lands. The main methods indicated in the scheme act as the primary means of solving the problems of effectively using agricultural land, particularly degraded and low-productive land. Regulation of land relations creates a balance between the rights of owners and the needs for sustainable use. Land use and conservation administration ensure responsible and balanced use of resources. Sustainable land-use management and spatial land-use management implement an integrated approach aimed at achieving sustainable development and degradation neutrality. Various tools are used in the process of organizational-economic support for the effective use of degraded and low-productive agricultural lands in the context of implementing the idea of LDN. The key ones are motivation, stimulation, awareness training, assessment, organization and monitoring.

Motivation and incentives are used to encourage landowners and land users to participate actively in the rehabilitation of lands and efficient land-use programs. Awareness training plays an important role in developing a conscious and responsible approach to the conservation and use of natural resources. Assessment provides an objective assessment of the effectiveness of measures and makes necessary adjustments to achieve the set objectives. Organization and monitoring are necessary to systematically monitor the execution of plans and to identify new opportunities to optimize processes. These tools interact to create a highly effective mechanism for achieving sustainable agricultural land use and degradation neutrality. Their implementation helps to strike a balance between economic and environmental aspects, thus contributing to sustainable development and the conservation of natural resources for future generations.

The proposed scheme also outlines the main stages of ensuring the effective use of degraded and low-productive agricultural land in the context of implementing the idea of LDN, particularly:

The first stage – land database development – includes an inventory and survey of lands to create a complete and accurate database. This involves collecting and analyzing various information resources such as geodata, soil characteristics, geobotanical indicators, and other relevant data. This process provides a comprehensive overview of the land state and characteristics necessary for the next steps.

The second stage – land-use planning – involves the development of land-use planning strategies based on the data obtained. This stage includes determining the intensity of land use, considering its purpose and needs for rehabilitation. Land zoning is a key element for optimizing land use and ecosystem restoration.

The third stage – project solutions for a comprehensive plan – involves developing a comprehensive plan that integrates the management of degraded and low-productive agricultural lands. This stage identifies optimal solutions to improve the condition and efficient use of these lands, considering sustainable development and the principles of the ecosystem approach.

Each of these stages includes a number of key actions and methods, considering the principles of the ecosystem approach and aimed at achieving LDN.

The proposed scheme can serve as a basis for developing land-use planning strategies for territorial communities. For institutions and organizations competent in the field of land resource management, the scheme can be a tool for the rational allocation and use of degraded lands. And for agricultural enterprises, the scheme may be useful in developing business plans and strategies aimed at the effective use of degraded and low-productive lands, taking into account economic and environmental aspects. In general, the application of the proposed scheme helps to solve problems with soil degradation and achieve the maximum agricultural land potential by planning land use through the prism of the ecosystem approach. This helps to conserve biodiversity, provide food, and stimulate the development of agricultural areas.

Research aimed at achieving land degradation neutrality (LDN) through land-use planning and an ecosystem approach emphasizes the importance of integrating various policies and coordinating stakeholders across different sectors. LDN aims to balance land degradation by ensuring that positive outcomes (through restoration or sustainable practices) compensate for losses, thereby maintaining a stable or improved state of ecosystems.

Key findings from current research indicate that land-use planning plays a crucial role in achieving land degradation neutrality (LDN) by implementing sustainable practices in sectors such as agriculture, forestry, and urban development. For example, agroforestry and green infrastructure in urban areas can enhance both carbon sequestration and land productivity, contributing to the achievement of LDN goals. Effective land-use planning requires the integration of ecological, economic, and social aspects to address complex challenges such as desertification, soil erosion, and loss of biodiversity (Gichenje et al., 2019; Gunawardena et al., 2024).

However, difficulties arise due to the fragmentation of policies and the need for better coordination among stakeholders. Research indicates that a unified political environment is necessary to integrate LDN objectives at all levels of governance—from local to national. There is also a need for improved data collection on soils and land resources, mobilization of financing, and more standardized management structures (Kust et al., 2016).

In the methodological aspect, the research recommends using spatial planning tools and models that allow for the assessment of land degradation risks and tracking restoration efforts. This helps to align LDN actions with other sectors, such as climate resilience and economic development (Briassoulis, 2019; UNCCD/Science-Policy Interface, 2022).

Other studies on land degradation neutrality (LDN) also emphasize the importance of an ecosystem approach and the integration of sustainable land resource management. For example, the study (Haiyan et al., 2022), highlights the need to integrate methods for assessing land degradation neutrality with ecosystem services to achieve global sustainable development goals, noting that LDN can be used as an indicator of effective ecosystem management, particularly through monitoring changes in land cover, land productivity, and soil organic carbon content.

Similarly, the study by Cowie et al. (2018) states that LDN requires consideration of the "ecosystem balance between degradation and restoration" and emphasizes that to achieve LDN, it is necessary to "ensure appropriate indicators for monitoring changes in land condition and developing effective management methods" (Cowie, 2020).

A common way of dealing with soil erosion and rehabilitating already eroded land is agroforestry – a system and technology of land use that combines crop production, livestock farming, horticulture, and forestry within the boundaries of a farm, community, or a certain space (Agroforestry Strategic Framework. Fiscal Years 2019–2024, 2019). Agroforestry is defined as a dynamic and ecologically sound natural resource management method that combines land management with agricultural crops and woody vegetation. In practice, it diversifies and supports production to increase social, economic, and environmental benefits for land users at all levels. Agroforestry is also important for smallholder farmers and other rural residents, as it can improve their food security, income, and health.

Stopping and minimizing soil erosion processes is the first priority of SLM policy to achieve LDN. However, practice shows that the anthropogenic burden on land resources will continue through urbanization, expansion of infrastructure, involvement of land in agricultural production, etc. Therefore, simultaneously with soil conservation measures, it is necessary to rehabilitate already eroded lands with the aim of involving them not only in agricultural use but also for environmental purposes (for example, in an ecological network). The difference between the concept of LDN and existing soil erosion control strategies is that it includes the possibility of balancing unavoidable soil erosion (loss) through measures to restore the biological productivity of land in other areas (reproduction). That is, a state of neutrality is assumed to be achieved due to the absence of net losses of natural capital.

Despite the difficulty of achieving LDN, we still believe that this approach to solving the problem of soil erosion in Ukraine is acceptable. In particular, domestic scientists propose reducing the area of arable land by removing erosion-hazardous and degraded masses, which are recommended to be converted to more environmentally sustainable lands (hayfields, pastures, shrubs, forests, wetlands) through regeneration, conservation, rehabilitation, and transformation. Such views are consistent with the principles for developing measures to balance land degradation: priority for local rehabilitation – rehabilitation should be conducted within the same biogeographical territorial unit; the advantage of rehabilitation over degradation – the rehabilitated land area should exceed the degraded land area, since the degradation process can occur faster than the rehabilitation process, which can take up to several decades; balanced management should be conducted at local, regional, or national levels within the same biophysical or administrative framework within which land-use planning decisions are made, thus contributing to the effective implementation of decisions made.

As a result of Russia's military aggression, Ukraine suffered massive shelling, missile strikes, radiation pollution, air pollution, littering of territories, as well as problems with unburied or spontaneously buried bodies of the dead and landmines. This led to aggravation of economic, environmental, and social challenges, particularly in the field of food security both in Ukraine and globally. Military operations caused large-scale destruction of Ukraine's land resources, deterioration of soil quality, and increased degradation processes, resulting in damage to land resources and losses to owners and land users.

In addition to the problems related to land degradation in Ukraine indicated in the study, a full-scale invasion by the Russian Federation began in February 2022, characterized by extensive use of various weapons systems, military equipment, and ammunition, which lead to significant pollution and destruction of the soil cover, intensifying the number and degree of degraded lands. The use of various types of ammunition (high-explosive, armor-piercing, cumulative projectiles, and mines) creates shock waves and explosion products that spread in the environment, causing soil deformation. During the burning, explosion, and detonation of munitions, toxic or hazardous products are formed that pollute the soil.

Unfortunately, a full assessment of the scale and level of land pollution will only be possible after the complete cessation of hostilities. Currently, more than 25% of lands in Ukraine need demining or survey (ZN,UA Mirror of the week, 2024). It should also be noted that a significant territory of Ukraine is currently under occupation: as of the beginning of 2024, Russia occupies a total of 109,000 square kilometers of Ukrainian territory (before the start of full-scale invasion in 2022, about 7% of Ukraine's territory was occupied (Denkovych, 2024)). Therefore, the study aims to analyze, articulate, and justify the need to introduce measures to achieve LDN, within which the author's conceptual approach for organizational-economic support for the effective use of degraded and low-productive agricultural land is implemented in the context of LDN implementation.

4 Conclusion

Having examined the existing state of land degradation in Ukraine, ways to achieve LDN have been substantiated, particularly through land-use planning based on an ecosystem approach. Based on statistical data and previous studies, indicators of arability have been calculated by natural-climatic zones, as well as the current and potential levels of arability of the territory of Ukraine. Additionally, the areas of eroded arable lands have been determined by the degree of erosion (low-eroded, medium-eroded, and highly-eroded).

The analysis revealed that approximately 8.6 million hectares of arable land in Ukraine require conservation, a significant portion of which is low-productive or erosion-prone. Studies have also found that erosion results in substantial losses of humus, which negatively impacts soil fertility. To prevent further degradation, it is proposed to implement soil protection and anti-erosion measures, as well as to withdraw eroded lands from intensive cultivation, converting them into meadows, pastures, or forested areas.

An important element of sustainable land resource management is the implementation of an ecosystem approach that combines the management of land, water, and biodiversity. Spatial planning should promote the optimal use of land, taking into account ecological, social, and economic needs. Achieving land degradation neutrality requires the development of a set of measures aimed at minimizing or restoring eroded lands.

The proposed scheme for the organizational and economic support of the effective use of degraded and low-productive lands will help balance landowners' rights with the need for sustainable use. The implementation of this scheme will contribute to increasing land productivity, preserving natural capital, and ensuring the sustainable development of rural areas. Particular attention should be paid to agroforestry, which is an effective method for restoring eroded lands and enhancing productivity through the combination of agricultural and forested areas.

In general, achieving land degradation neutrality requires an integrated approach to land use management at the local, regional, and national levels, which will allow for the preservation of natural resources and ensure long-term ecological stability.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Author contributions

PS: Funding acquisition, Project administration, Resources, Visualization, Writing–original draft, Writing–review and editing. IK: Conceptualization, Funding acquisition, Investigation, Supervision, Writing–original draft. LB: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Writing–original draft, Writing–review and editing. NS: Formal Analysis, Resources, Validation, Writing–original draft. AR: Investigation, Resources, Validation, Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study was carried out as part of the project "Belt and Road Initiative Centre for Chinese-European studies (BRICES)" and was funded by the Guangdong University of Petrochemical Technology. The research was carried out with the support of the Ministry of Education and Science of Ukraine (project 0124U000290) "Tourist revitalization of industrial facilities to ensure social and economic security of territorial communities" and (project 0121U109407) "Theoretical and methodological principles of land resource management and the development of the national economy in the conditions of ensuring sustainable development".

Acknowledgments

The authors are grateful to the editor and reviewers for their comments that helped improve the content of this paper.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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