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FOREIGN EXPERIENCE IN THE RESTORATION OF DEGRADED LANDS: A LANDSCAPE-APPROACH ANALYSIS AND RECOMMENDATIONS FOR THE TASHKENT REGION

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Abstract

The article analyses international experience in restoring degraded lands from the perspective of the landscape approach. Reclamation models applied in Germany, Poland, the USA, Canada, China, Kazakhstan and Mongolia, as well as international methodological frameworks developed by FAO and UNEP/UNCCD, are comparatively examined. Based on the findings, a “coordinated model” adapted to the conditions of the Tashkent region is proposed, comprising a legal basis, landscape-appropriate ecological restoration, use of native flora and fauna, involvement of the local population, and a monitoring system.

Keywords: Degraded lands, reclamation, landscape approach, restoration, Tashkent region, sustainable land management, bioremediation.

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INTRODUCTION

Land resources play a decisive role in ensuring the economic and ecological sustainability of humankind. As a result of industrial activity, mining, construction, and other economic operations, degraded lands lose their natural state, and their capacity to perform ecosystem services is substantially reduced. International experience shows that in the process of restoring such areas, the landscape approach is one of the most effective methods for reconciling ecological, social, and economic factors ^[1]. Over recent decades, international organizations such as the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), and the International Union for Conservation of Nature (IUCN), as well as countries including Germany, the USA, Canada, China, and Poland, have been implementing large-scale programmes for the reclamation of degraded lands, placing the principles of sustainable landscape management at the forefront of their national strategies ^[2, 3].

The reclamation of degraded lands has been widely discussed worldwide, resulting in the development and refinement of reclamation schemes in various countries ^[4]. Practical experience shows that existing approaches differ considerably and do not fully meet the requirements of ecosystem hierarchy and lower-level productivity ^[5, 6]. Although no single set of international regulatory documents exists, methodological gaps are observed even in countries with national legislation ^[7].

In Uzbekistan, and particularly in the Tashkent region, the area of degraded land is increasing year by year as a result of mining, construction-material production, and other economic activities. The region's location within a dry climatic zone transitioning from subtropical to temperate conditions, its foothill-mountain zone, and the altitudinal zonation of its landscapes require that international experience in restoring such areas be applied not mechanically, but adapted to local natural-geographic conditions.

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The aim of the study is to analyse foreign experience in restoring degraded lands from the perspective of the landscape approach and to substantiate a restoration model adapted to the conditions of the Tashkent region. To achieve this aim, the following tasks were set: 1) to analyse the experience of developed countries (Germany, Poland, the USA, Canada, China) and of countries with similar natural-climatic conditions (Kazakhstan, Mongolia); 2) to study the methodological approaches of international organizations (FAO, UNEP/UNCCD); 3) to develop, on the basis of the experience studied, a coordinated restoration model for the Tashkent region.

MATERIALS AND METHODS

The material for the study comprised 24 scientific sources published between 1997 and 2025 — international peer-reviewed journals (Ecological Engineering, Journal of Applied Ecology, Land Degradation & Development, Science of the Total Environment, Remote Sensing, PLoS ONE, and others), monographs, and official documents of international organizations such as FAO, UNCCD, and USDA. Sources were selected according to the following criteria: a) direct relevance to the reclamation of degraded/disturbed lands; b) coverage of the landscape approach or the concept of ecosystem-based restoration; c) inclusion of empirical data or long-term monitoring results.

The study employed comparative-analytical and content-analysis methods. Seven countries (Germany, Poland, the USA, Canada, China, Kazakhstan, and Mongolia) and two international organizations (FAO, UNEP/UNCCD) were selected for analysis. This selection was justified by the fact that these countries possess long-term, well-documented experience in restoring lands degraded by mining and industrial activity, and that some of them (Kazakhstan, Mongolia) share dry and semi-desert climatic conditions similar to those of the Tashkent region.

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The experience of each country was systematized according to four parameters: (1) the main approach or methodology applied; (2) the scientific and practical advantages of the approach; (3) the quantitative/qualitative indicators achieved (where available); (4) the possibilities for adaptation to the natural-geographic conditions of the Tashkent region (a dry climate transitioning from subtropical to temperate, a foothill-mountain zone, and altitudinal landscape zonation). The results of this systematization are summarized in Table 1. Based on the conclusions drawn, a comprehensive (“coordinated”) restoration model for the Tashkent region was formulated inductively.

RESULTS

European experience: Germany and Poland

Germany is one of the leading countries in Europe in restoring degraded lands. In the country, a comprehensive and systematic approach to the reclamation of lands degraded mainly by mining and industrial activity has been established, and this process is regulated under the “Federal Soil Protection Act.” According to this act, every degraded plot of land is required to have an individual reclamation plan [8]. In modern approaches to landscape restoration, the principle of reconciling ecological, social, and economic objectives is of primary importance; however, in some cases the level of social engagement and effective cooperation with stakeholders is not given sufficient attention [9].

The methodology applied in the German experience includes several key stages: identifying and classifying landscape characteristics; assessing the degree of landscape disturbance; restoring natural flora and fauna; and adapting the area for agricultural, recreational, or other sustainable uses. This experience can also be applied under the conditions of the Tashkent region: taking into account the region's climatic characteristics, stabilizing vegetation cover in mining areas and introducing methods that combine forestry and agriculture would increase the effectiveness of restoration.

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In the Polish experience, approaches to restoring post-mining lands are considered advanced by European standards. In preparing open-pit mines, coal-waste dumps, and sand-quarry areas for reuse, the main strategy is afforestation, in which indicators such as energy balance, carbon sequestration, and the energy efficiency of the landscape are taken into account. Studies show that reclaimed forests achieve higher carbon accumulation and energy efficiency than forests formed through natural succession ^[10]. In the reclamation process, the choice of plant species is matched to the characteristics of the mining-waste substrate: pioneer species adapted to low-fertility environments, in particular pine, are planted, with subsequent enrichment using mixed deciduous species recommended ^[11].

The reclamation plan for open-pit lignite mines covers all stages, from land acquisition to the transfer of the site for reuse after mine closure, and is documented through clearly defined management practices ^[12]. Studies generalizing Central and Eastern European experience propose an optimized model based on the triad of “substrate × plant species × management” ^[13]. In addition, research on bioenergy crops, including *Salix viminalis* (willow), shows — through assessment of soil moisture, physicochemical properties, and biofuel quality indicators — that this species can effectively bring degraded or low-fertility lands into productive use ^[14]. Studies conducted over the past decade have found that on mining-waste heaps, forbs achieve higher nutrient-uptake efficiency than cereal crops under all conditions ^[15]. In applying these experiences to the conditions of the Tashkent region, it is necessary to take into account the continental character of the climate, the hot and dry summer season, and the limited availability of soil moisture.

North American experience: Canada and the USA

In Canada, the areas of open-pit oil-sands mining in the province of Alberta are distinguished by the disturbance of boreal coniferous forest and peatland

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ecosystems. Studies show that when post-mining soil profiles are reconstructed, in particular through the introduction of peat-mineral layers, the main functions of the soil can be restored within 15 years ^[16]. However, other studies show that in areas of open-pit oil-sands mining, a large proportion of peat bogs is destroyed, resulting in a sharp decline in carbon reserves, with millions of tonnes of carbon released into the atmosphere annually ^[17]. In Canada, the restoration process is divided into three main components: soil restoration ^[16]; an approach aimed at restoring carbon reserves, although it has been found that the original peatland's full carbon balance cannot be fully restored ^[17]; and monitoring based on the regular observation of nutrient cycling, vegetation-cover structure, and soil processes. In applying these experiences to the Tashkent region, it is recommended not to fully replicate the Canadian model but to adapt its underlying principles — using a mixture of organic and mineral materials, assessing evapotranspiration (ET) indicators, and selecting local pioneer species tolerant of drought and salinity.

In the American experience, the Forestry Reclamation Approach (FRA) includes forming soil from high-quality base layers, using low-density mineral mixtures and organic layers, and applying a tree-planting strategy suited to landscape characteristics. This approach is effective not only ecologically but also economically and socially, and plays an important role in restoring ecosystem services ^[18]. According to long-term observations conducted by Holl ^[19] in the Appalachian region, more than 10 years after the restoration process, plant communities had recovered to a state very close to the original forest ecosystems. Using the chronosequence method as a technique for precisely measuring soil quality and properties, significant improvement over time was found in soil components (silt, clay, organic carbon) in reclaimed areas ^[20]. Involving local plant and animal species in the restoration process, and engaging them in ecosystem-service and green-economy projects, would be effective for the Tashkent region.

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Asian experience: China, Kazakhstan, and Mongolia

In China, land degradation caused by industrialization and urbanization is one of the most pressing environmental problems. To address this problem, the government is implementing strategic programmes aimed at converting mining areas into agroforestry systems, establishing anti-erosion forests, and creating artificial water reservoirs ^[21]. Large-scale ecological projects carried out on the Loess Plateau over recent decades, including the “Grain for Green Program,” have significantly reduced soil erosion, increased biological diversity, and helped restore hydrological balance ^[22]. This approach could also prove effective under the conditions of the Tashkent region.

Research conducted at the Kokjon phosphorite deposits in the semi-desert zone of Kazakhstan has provided clear scientific evidence of the effectiveness of the bioremediation approach. Restoration work was carried out over 6,400 hectares by enriching the soil with urea and planting local plant species — Russian olive (*Elaeagnus*) and black saxaul. As a result, vegetation cover expanded from 60% to 80%, productivity increased from 2,200 kg/ha to 3,300 kg/ha, and soil humus content rose from 0.18% to 1.14%. At the same time, long-term monitoring recorded a 47.6% decline in humus and a 28.4% decline in vegetation productivity — indicating that the restoration process requires continuous agrotechnical and ameliorative measures ^[23] (Figure 1).

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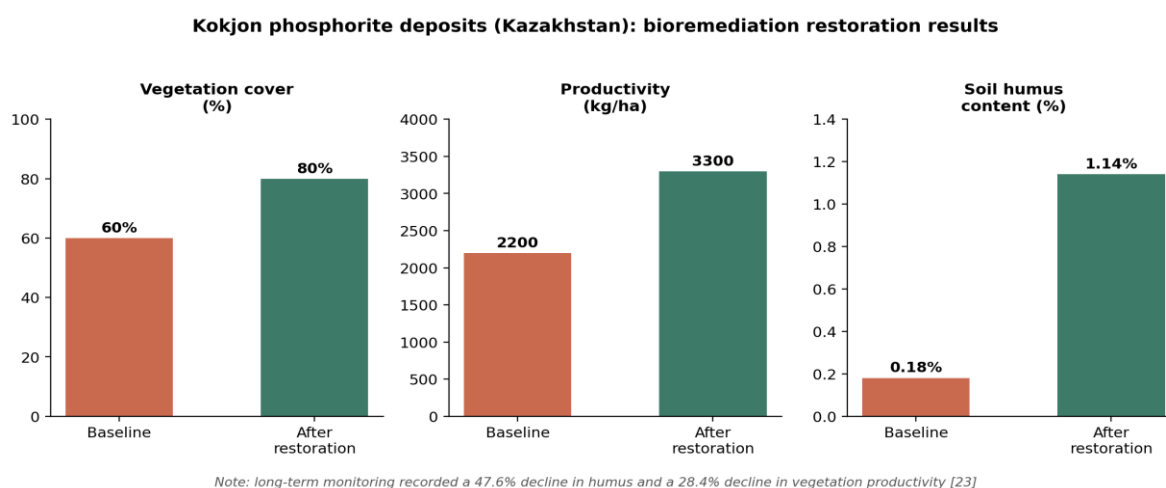


Figure 1. Restoration results of bioremediation at the Kokjon phosphorite deposits (Kazakhstan) [23]

In Mongolia, the restoration of land resources is closely linked to landscape monitoring. Using remote-sensing technologies to systematically analyse land-cover changes in Kazakhstan and Mongolia, it has been found that most of Mongolia's territory, particularly Dornod Province, is covered by up to 91.5% grassland, with the main observed changes related to the conversion of pastureland into cropland [24]. This situation clearly reflects the interaction between changes in land use and restoration policies. Based on the Kazakh experience, it is recommended that, for degraded lands in the region, plant species suited to local climate and soil conditions be selected, that soil be enriched with urea, and that productivity and humus content be regularly monitored. The Mongolian experience, based on remote monitoring, is important for identifying land-cover changes and for developing strategies for the sustainable management of pastureland and agricultural land.

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Methodology of international organizations

The “Sustainable Land Management” concept developed by the Food and Agriculture Organization of the United Nations (FAO) establishes the methodological foundations for applying the landscape approach in restoring degraded lands [2]. This concept puts forward the following key recommendations: mapping landscape units and assessing the degree of disturbance; involving the local population in the restoration process and using local plant and animal species; and conducting long-term monitoring of restored lands. UNEP/UNCCD, through its “Land Degradation Neutrality” (LDN) programme, has established commitments for states to halt and reverse land degradation by 2030 [3].

Table 1. International experience in restoring degraded lands and its relevance to the Tashkent region

Country / Organization	Main approach	Advantages	Relevance to the Tashkent region
Germany [8]	Mandatory restoration under federal law; landscape approach	Strong legal framework; long-term monitoring system	Integration into legislation; establishing a monitoring and control system
Poland [10]	Technical and biological restoration	Bioenergy-crop plantations; restoration of soil fertility	Planting bioenergy crops; developing bioenergy opportunities
USA [18, 19, 20]	Forestry Reclamation Approach (FRA); long-term monitoring	Restoring soil layers with high-quality substrates; revegetation with local flora	Restoring mined or degraded lands through agroforestry combinations; establishing a monitoring system
Canada [17]	Ecoregion approach	Adaptation based on landscape classification	Developing individual strategies for each land type

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Country / Organization	Main approach	Advantages	Relevance to the Tashkent region
China [21, 22]	Agroforestry integration	Anti-erosion forests; plant species suited to desert conditions	Planting sustainable vegetation resistant to wind erosion
Kazakhstan [23]	Restoration based on steppe vegetation, soil, and biogeographic characteristics	Restoring pasture species; increasing local herbaceous resources	Reducing pasture degradation; reintroducing local forage plants
Mongolia [24]	Ecological restoration of mining areas	Locally adapted plant species; climate-appropriate agrotechnics	Adapting reclamation strategies for arid-climate regions
FAO [2]	Sustainable land management	Mapping landscape units; involving the local population; long-term monitoring	Applying landscape-adapted mapping and monitoring systems to the study area
UNEP/UNCCD [3]	LDN (Land Degradation Neutrality) concept	Integrated approach	Alignment with international standards

Table compiled by the author

DISCUSSION

The comparative analysis conducted shows that although the overall ecological goal of restoring degraded lands is the same across all the countries examined, the practical means employed vary considerably depending on each region's natural-geographic, climatic, and socio-economic conditions. In the German and Polish experience, the sustainability of geosystems has been ensured through a combination of a strong legal framework, rigorous monitoring systems, and technical-biological approaches. In the Canadian model, restoring soil based on peat-mineral substrates together with continuous monitoring is a core element, while in the USA, methods such as FRA combine ecological and social benefits.

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China's large-scale ecological programmes are aimed at reducing erosion and increasing biological diversity, Kazakhstan has achieved increased productivity in semi-desert zones through bioremediation measures, and Mongolia is improving the effectiveness of pasture-resource management through remote-sensing-based landscape monitoring.

At the same time, as the Kazakh example shows (Figure 1), the initial positive results of bioremediation measures do not remain stable without long-term monitoring: the subsequent decline in humus and productivity indicators confirms the need for continuous agrotechnical and ameliorative control. This conclusion is particularly significant for the Tashkent region, since under the region's dry continental climate and limited moisture reserves, short-term restoration measures may fail to produce sustainable results.

The experience of United Nations organizations (FAO, UNEP/UNCCD) establishes the mapping of landscape units, engagement of the local population in the process, and long-term monitoring as the core methodological principles at the global level. The experience of the countries reviewed above can be applied in the Tashkent region, but it must be adapted to the region's natural-geographic conditions, based on its dry climatic zone transitioning from subtropical to temperate, its foothill-mountain zone, and the altitudinal zonation of its landscapes.

For this reason, a coordinated model for restoring degraded lands under the conditions of the Tashkent region is proposed (Figure 2): legal basis + landscape-appropriate ecological restoration + use of local plant and animal species + involvement of the local population + monitoring system.

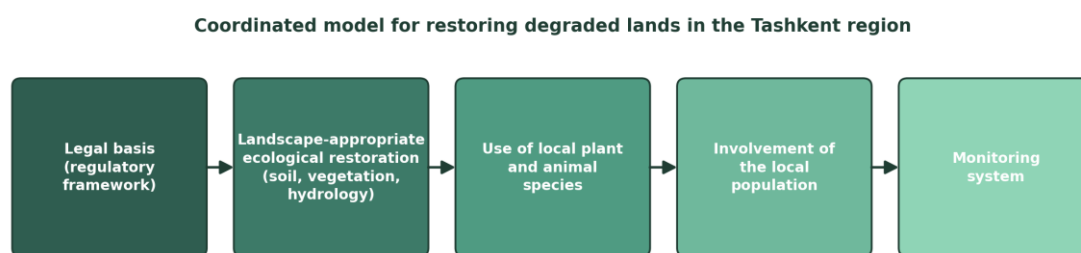
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Compiled by the author based on the analysis of foreign experience

Figure 2. Coordinated model for restoring degraded lands under the conditions of the Tashkent region (compiled by the author)

A limitation of the study is that most of the foreign experience reviewed was accumulated in climatic zones different from that of the Tashkent region (humid temperate, boreal, monsoon), and only the experience of Kazakhstan and Mongolia directly reflects a similarly dry climate. For this reason, the proposed model is preliminary and generalized in character, and testing it in specific areas of the Tashkent region under real conditions remains a task for future research.

CONCLUSION

The analysis conducted shows that the effectiveness of restoring degraded lands depends, above all, on the degree to which the approach is systematic, technologies are selected to suit local conditions, and stakeholders are actively engaged. The experience of Germany, Poland, Canada, the USA, China, Kazakhstan, and Mongolia shows that, although restoration strategies are directed toward common ecological goals, their practical methods are adapted to the natural-geographic, climatic, and economic conditions of each region ^[1, 9]. The five-stage coordinated model proposed for the Tashkent region — legal basis,

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landscape-appropriate ecological restoration, use of local biodiversity, engagement of the population, and continuous monitoring — combines the most effective aspects of foreign experience, adapted to the region's natural-geographic characteristics, and can serve as a basis for future applied research.

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