

IMPROVING THE MANAGEMENT OF ECOLOGICAL MODERNIZATION OF PRODUCTION IN AZERBAIJAN: A TECHNICAL AND ECONOMIC APPROACH

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Summary. This study examines the technical and economic approaches to the effective management of ecological restructuring of production in the regions of Azerbaijan within the framework of sustainable regional development. The research applies an integrated economic-geographical approach and considers natural resource potential, production structures, environmental pressures, capital investment, technological modernization, and environmental monitoring. System-structural, mathematical-statistical, geographic information system (GIS), and monitoring-based methods are used to assess the relationship between production development and environmental protection. The results indicate that ecological restructuring requires the economical and comprehensive use of natural resources, modernization of production technologies, expansion of closed-cycle and low-waste systems, reduction of harmful emissions, and development of specialized treatment facilities. Particular attention is given to industrial and environmental conditions in the Absheron Peninsula, Baku, Sumgayit, and other production areas of Azerbaijan. The analysis demonstrates that technological modernization and water-reuse systems can reduce resource consumption and environmental pressure while supporting production efficiency. The study also emphasizes the importance of environmental investment and scientifically based monitoring for effective regional management. It concludes that ecological restructuring should integrate technological innovation, resource efficiency, pollution prevention, environmental investment, and territorial planning within a unified management framework.

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1. Introduction

The ecological restructuring of production has become an important component of sustainable regional development as economic growth increasingly depends on the efficient use of natural resources and the reduction of environmental pressures. In Azerbaijan, the interaction between industrial development, resource consumption, and environmental conditions requires an integrated economic and ecological approach to production management.

Existing studies have addressed different aspects of regional development and environmental management; however, the technical and economic mechanisms linking production restructuring with sustainable regional development remain insufficiently integrated. Ecological restructuring should therefore be considered not only as an environmental measure but also as a component of technological modernization, resource management, and territorial development.

Ecological restructuring of production reflects the interaction between social production and the natural environment and encompasses a broad range of economic and technological measures affecting industry, agriculture, and other sectors (Özal, 2019). Its implementation requires a systematic approach that combines the rational use and reproduction of natural resources, pollution prevention, technological improvement, and environmental protection.

Accordingly, this study aims to identify the principal technical and economic approaches to the effective management of ecological restructuring of production in Azerbaijan, with particular attention to resource efficiency, technological modernization, environmental monitoring, treatment infrastructure, and sustainable regional development.

2. Material and method

The study examines the territorial and structural characteristics of ecological restructuring of production in Azerbaijan and the technical and economic approaches to its effective management. The analysis considers regional differences in natural resource potential, production structures, capital investment, technological infrastructure, and environmental conditions. Particular attention is given to the relationship between economic development, resource use, and environmental pressures across industrial regions of the country (Mammadov, 2014).

The methodological framework combines system-structural, mathematical-statistical, geographic information system (GIS), and environmental monitoring methods. The assessment also considers factors influencing ecological restructuring, including natural resource potential, established production patterns, the initial level of economic development, and the territorial organization of production. These methods are used to identify regional differences, evaluate economic-environmental relationships, and determine the principal technical and economic directions of ecological restructuring within the framework of sustainable regional development.

3. Problem statement and research results.

The effective management of ecological restructuring should simultaneously address social demand for natural resources, improve the efficiency of resource use, support resource reproduction, and ensure the economical use of non-renewable resources. Scientific and technological progress has expanded the scale of production and intensified its interaction with the natural environment, increasing the importance of technological modernization and environmentally oriented resource management (Mammadov, 2016).

Ecological restructuring and the reproduction of natural resources are closely interconnected. Modern production systems therefore require not only efficient resource use but also measures aimed at preventing and mitigating environmental degradation. Environmental protection should be integrated into production management because ecological restructuring cannot be effectively implemented independently of measures designed to maintain environmental quality and ecological balance.

The Jeyranbatan Reservoir illustrates this relationship. As an important source of water supply for Baku and Sumgayit, its relatively limited self-purification capacity increases its vulnerability to industrial, agricultural, and domestic pollution. Consequently, the management of production activities affecting the reservoir must be closely linked to water protection and pollution-prevention measures.

Ecological restructuring also includes measures such as wastewater and air purification, land reclamation, and the elimination of major sources of water and air pollution. These measures are closely related to the regenerative functions of natural ecosystems. For example, forest ecosystems contribute to water conservation, carbon absorption, and oxygen production, demonstrating that environmental protection and resource reproduction should be considered complementary components of ecological restructuring (Bityukova, 2017).

Industrial development has substantially altered environmental conditions in several production areas of Azerbaijan. The Absheron Peninsula provides a notable example, where long-term oil production and related industrial activities have contributed to the accumulation of petroleum waste and pollutants in soils and groundwater. These conditions demonstrate the importance of integrating pollution prevention, environmental remediation, and ecological monitoring into the restructuring of industrial production.

Effective environmental management requires scientifically based monitoring capable of identifying changes in environmental conditions and supporting timely management decisions (Ivanova, 2021). Monitoring should combine sanitary-hygienic observations related to population health with geocological assessment of changes occurring in natural and economic systems under anthropogenic pressure. Such an integrated approach provides an information basis for evaluating environmental risks and planning ecological restructuring measures.

Monitoring activities conducted in the oil- and gas-producing areas of the Absheron Peninsula have also contributed to the development of an electronic environmental database. The database contains spatial information on land contaminated by oil and other wastes, areas affected by formation waters, and the depth and location of contamination. The integration of these data with precise geographic coordinates can support the identification of environmentally vulnerable areas and improve the management of economic and environmental problems.

Environmental protection and production development should be considered as complementary rather than competing objectives. The modernization of production requires the systematic incorporation of ecological principles into technological and managerial decisions (Nuriyev, 2017). Accordingly, ecological restructuring should encompass all major components of the production system and should be closely linked to scientific and technological progress.

In Azerbaijan, one of the principal objectives of ecological restructuring is to combine economic development with technological modernization and more efficient use of natural resources. This process involves improving production technologies, reducing resource consumption and harmful emissions, and developing specialized treatment facilities (Mammadov, 2014). The interaction between scientific and technological progress and production is illustrated in Figure 1.

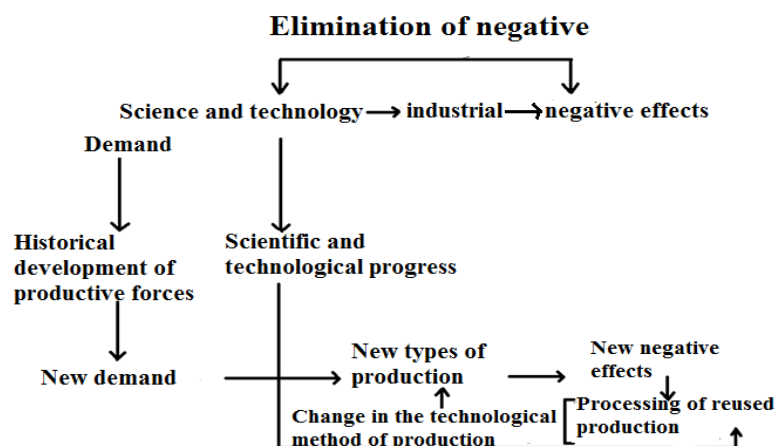


Fig. 1. Interaction between scientific and technological progress and production

The further development of ecological restructuring requires a transition from low-waste technologies to closed-cycle and, where technically feasible, waste-free production systems. Such systems promote the reuse of waste and by-products between enterprises, reduce demand for primary resources, and strengthen production linkages within territorial-industrial complexes (Mammadov, 2020). Previous industrial experience in Azerbaijan demonstrates the practical potential of this approach. For example, closed technological processes at the Sumgayit synthetic rubber plant enabled production waste to be used as a secondary resource in the manufacture of products such as sulfuric acid, alcohol, and styrene. Thus, in the former Soviet period, conditions were created in our country for the production of sulfuric acid, alcohol, and styrene from the waste of the Sumgayit synthetic rubber plant in connection with the transition to a closed technological process, which ensured an additional annual increase in the efficiency of enterprises.

Analysis of the obtained data demonstrates that technological modernization has significantly reduced water consumption in industrial production. In the 1970s, the designed water consumption at Baku oil refineries reached 8 units per ton of product; by the mid-1980s, water demand had decreased approximately tenfold. Further ecological restructuring, including the expansion of water circulation and reuse systems, contributed to an additional reduction in water consumption. Closed-cycle water-use systems were also introduced at chemical enterprises in Sumgayit. As a result, water withdrawal from natural water bodies decreased by approximately 35–40%, while production increased by 25–30% (Mammadov, 2019).

These results indicate that ecological restructuring of production should be developed in two interrelated directions: (1) the rational and comprehensive use of natural resources, particularly mineral raw materials and water resources; and (2) the reduction or, where possible, elimination of negative environmental impacts associated with production processes.

Environmental investment is another important component of ecological restructuring. Although environmental protection measures do not always generate immediate economic returns, they contribute to the conservation of essential natural resources and the maintenance of environmental quality. With the development of modern production, the share of investment directed toward environmental protection has also increased internationally (Bityukova, 2017). In several industrial sectors of Western countries, environmental investment has accounted for approximately 20–25% of total investment, particularly in metallurgy, the pulp and paper industry, oil refining, the chemical industry, and electric power generation.

In Azerbaijan, the share of environmental expenditure in capital investment and operating costs has also increased. According to the statistical data used in the study, environmental protection expenditure increased from 30.8 thousand manats in 1991 to 387 million manats in 2019 (Environment in Azerbaijan, 2020). Funds allocated to fixed capital for the efficient use of natural resources and environmental protection increased from 9.2 thousand manats in 1991 to approximately 350 million manats in recent years. Environmental expenditure has been particularly concentrated in the oil, energy, chemical, and petrochemical industries. Compared with the average expenditure across material-production sectors, the corresponding level was reported to be 2.8 times higher in the chemical and petroleum industries and 2.3 times higher in the power industry (*Regionların sosial-iqtisadi inkişafı*, 2016).

Environmental investment also varies among individual industrial sectors and production complexes. According to the estimates considered in the study, capital expenditure for environmental protection in the thermal and electric power sector amounted to 13.5 manats per 1,000 kV, while investment in water and air purification in the Ganja non-ferrous metallurgy complex accounted for approximately 6–8% of total capital expenditure. In several other processing industries, purification-related investment reached 20–25%.

One of the most important criteria for introducing new technology is its environmental performance compared with the technology previously used, particularly its ability to reduce harmful emissions per unit of production. However, the environmental efficiency of a new technological model should not be assessed independently of the regional or local conditions in which it is applied.

Accordingly, a comprehensive assessment of pollution is an important stage in evaluating both the environmental effectiveness of new equipment and the efficiency of environmental expenditure. Such an assessment makes it possible to evaluate the application of new equipment within regional territorial-production complexes over its projected service life. The expected volume of pollution associated with the introduction of new technology can be expressed as:

$$Q_{yt} \leq Q_{ck} \cdot X_{ts} \cdot P_{om}$$

Here Q_{yt} – the expected volume of pollution when using a new technique; Q_{ck} – the mass of pollution resulting from the use of one technique or a single technological process per year; X_{ts} – the number of existing techniques used in the country's economy per year; P_{om} – the predicted average service life of new techniques. In our country, when eliminating possible deterioration of the ecological situation of production, the following conditions should be expected. That is, when replacing an old technology with a new technology, the deterioration with the new technology should be smaller than the deterioration with the old technology ($Q_{new\ tec.} < Q_{old\ tec.}$). In exceptional cases, the deterioration with the new technology may be equal to the deterioration with the old technology ($Q_{new\ tec.} = Q_{old\ tec.}$). If these requirements are not met, the existing models will need to be progressively improved.

Thus, one of the main goals of ecological restructuring of production is the creation of new technology. It should also be noted that the allocation of costs and their application is not an easy task. In this regard, it is proposed to either allocate a new model in the composition of a technological circle with a special ecological purpose, or to solve existing new models, taking a conditional share of the problem as a whole, corresponding to the urgency of ecological problems.

The determination of the absolute effectiveness of environmental protection measures, the application of ecologically reconstructed equipment and the disclosure of the sequence of capital invested in environmental protection in various sectors of the economy. All this leads to the necessity of including in economic calculations of losses or negative effective indicators, the results of economic activity.

4. Conclusion

The study demonstrates that the effective management of ecological restructuring of production in Azerbaijan requires an integrated economic and environmental approach based on the interaction between production systems and the natural environment. Such an approach should combine technological modernization, rational use of natural resources, environmental protection, and appropriate management mechanisms within regional development planning.

Ecological restructuring should not be considered an obstacle to economic development but rather an essential component of sustainable production. Its effective implementation requires the gradual introduction of environmentally efficient technologies and management systems that reduce resource consumption and negative environmental impacts while improving production efficiency. Therefore, economic and environmental considerations should be integrated into planning and investment decisions to ensure the rational use of natural resources, improve environmental quality, and support sustainable regional development in Azerbaijan.

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СОВЕРШЕНСТВОВАНИЕ УПРАВЛЕНИЯ ЭКОЛОГИЧЕСКОЙ МОДЕРНИЗАЦИЕЙ ПРОИЗВОДСТВА В АЗЕРБАЙДЖАНЕ: ТЕХНИКО-ЭКОНОМИЧЕСКИЙ ПОДХОД

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Резюме. В исследовании рассматриваются технические и экономические подходы к эффективному управлению экологической реконструкцией производства в регионах Азербайджана в рамках устойчивого регионального развития. В работе применяется комплексный экономико-географический подход и рассматриваются природно-ресурсный потенциал, производственные структуры, экологические нагрузки, капитальные вложения, технологическая модернизация и экологический мониторинг. Для оценки взаимосвязи между развитием производства и охраной окружающей среды используются системно-структурные, математико-статистические методы, географические информационные системы (ГИС) и методы, основанные на мониторинге. Результаты показывают, что экологическая реконструкция требует экономного и комплексного использования природных ресурсов, модернизации производственных технологий, расширения систем замкнутого цикла и малоотходного производства, сокращения вредных выбросов и создания специализированных очистных сооружений. Особое внимание уделяется промышленным и экологическим условиям на Апшеронском полуострове, в Баку, Сумгаите и других производственных районах Азербайджана. Анализ показывает, что технологическая модернизация и системы повторного использования воды могут снизить потребление ресурсов и экологическую нагрузку, одновременно способствуя повышению эффективности производства. В исследовании также подчеркивается значение экологических инвестиций и научно обоснованного мониторинга для эффективного регионального управления. Сделан вывод о том, что экологическая реконструкция должна объединять технологические инновации, эффективность использования ресурсов, предотвращение загрязнения, экологические инвестиции и территориальное планирование в рамках единой системы управления.

Ключевые слова: экологическая реструктуризация производства, устойчивое развитие, управление природными ресурсами, экологические инвестиции, очистные сооружения, Азербайджан

AZƏRBAYCANDA İSTEHSALIN EKOLOJİ MODERNLƏŞDİRİLMƏSİNİN İDARƏ EDİLMƏSİNİN TƏKMİLLƏŞDİRİLMƏSİ: TEXNİKİ-İQTİSADI YANAŞMA

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Xülasə. Tədqiqatda dayanıqlı regional inkişaf çərçivəsində Azərbaycanın regionlarında istehsalın ekoloji yenidən qurulmasının səmərəli idarə edilməsinin texniki və iqtisadi istiqamətləri araşdırılır. Tədqiqatda kompleks iqtisadi-coğrafi yanaşma tətbiq edilir və təbii resurs potensialı, istehsal strukturları, ekoloji təzyiqlər, kapital qoyuluşları, texnoloji modernləşmə və ekoloji monitorinq nəzərdən keçirilir. İstehsalın inkişafı ilə ətraf mühitin mühafizəsi arasındakı əlaqənin qiymətləndirilməsi üçün sistem-struktur, riyazi-statistik, coğrafi informasiya sistemləri (CİS) və monitorinq əsaslanan metodlardan istifadə edilir. Nəticələr göstərir ki, ekoloji yenidənqurma təbii resurslardan qənaətli və kompleks istifadəni, istehsal texnologiyalarının modernləşdirilməsini, qapalı dövrüyyəli və az tullantılı sistemlərin genişləndirilməsini, zərərli emissiyaların azaldılmasını və ixtisaslaşdırılmış təmizləyici qurğuların yaradılmasını tələb edir. Abşeron yarımadasında, Bakı, Sumqayıt və Azərbaycanın digər istehsal ərazilərində sənaye və ekoloji şəraitə xüsusi diqqət yetirilir. Təhlil göstərir ki, texnoloji modernləşmə və suyun təkrar istifadəsi sistemləri istehsalın səmərəliliyini dəstəkləməklə yanaşı, resurs istehlakını və ətraf mühitə təzyiqi azalda bilər. Tədqiqatda, həmçinin səmərəli regional idarəetmə üçün ekoloji investisiyaların və elmi əsaslandırılmış monitorinqin əhəmiyyəti vurğulanır. Nəticə olaraq, ekoloji yenidənqurmanın texnoloji innovasiyaları, resurs səmərəliliyini, çirklənmənin qarşısının alınmasını, ekoloji investisiyaları və ərazi planlaşdırılmasını vahid idarəetmə çərçivəsində birləşdirməli olduğu müəyyən edilir.

Açar sözlər: istehsalın ekoloji yenidən qurulması, davamlı inkişaf, təbii resursların idarə edilməsi, ekoloji investisiyalar, təmizləyici qurğular, Azərbaycan