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ECOLOGICAL RESTORATION AND PRODUCTIVITY ENHANCEMENT OF FOREST ECOSYSTEMS

Abstract: *Forest ecosystems are among the most important natural components ensuring ecological stability, biodiversity conservation, climate regulation, and soil protection. However, increasing anthropogenic impacts, including illegal logging, overgrazing, and irrational land use, have led to significant degradation of forest ecosystems in mountainous regions. The present study investigates measures aimed at increasing forest productivity and restoring degraded forest ecosystems under changing environmental conditions.*

The research revealed that anthropogenic disturbances negatively affect forest structure, species composition, and natural regeneration processes, particularly in mountain and foothill forest belts. Soil erosion, reduction of forest density, and replacement of valuable edificatory species by shrubs and low-value vegetation were observed in many degraded forest areas. Restoration measures should therefore include strict protection of forest territories, limitation of grazing activities, prevention of illegal tree cutting, and implementation of natural and artificial afforestation programs.

Special attention was given to the selection of tree species adapted to degraded and erosion-prone environments. The results indicate that species such as Pinus eldarica, Pinus nigra, birch, and common pear demonstrate high adaptability and favorable growth under poor soil and dry climatic conditions. Artificial forest

plantations established on degraded slopes contribute to soil recovery, reduction of erosion processes, and gradual restoration of ecological balance.

The study emphasizes that sustainable forest management and ecosystem restoration require integrated ecological approaches combining afforestation, biodiversity conservation, erosion control, and rational utilization of forest resources. Implementation of scientifically based restoration measures will contribute to the improvement of forest productivity, stabilization of mountain landscapes, and long-term ecological sustainability.

***Keywords**: forest ecosystems, ecological restoration, anthropogenic impacts, afforestation, forest productivity, soil erosion, mountain forests, biodiversity conservation.*

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ЭКОЛОГИЧЕСКАЯ РЕСТАВРАЦИЯ И ПОВЫШЕНИЕ ПРОДУКТИВНОСТИ ЛЕСНЫХ ЭКОСИСТЕМ

***Аннотация:** Лесные экосистемы являются одними из важнейших природных компонентов, обеспечивающих экологическую стабильность, сохранение биоразнообразия, регулирование климата и защиту почв. Однако растущее антропогенное воздействие, включая незаконную вырубку лесов, чрезмерный выпас скота и нерациональное землепользование, привело к значительной деградации лесных экосистем в горных регионах. В настоящем исследовании изучаются меры, направленные на повышение продуктивности лесов и восстановление деградированных лесных экосистем в условиях меняющейся окружающей среды.*

Исследование показало, что антропогенные воздействия негативно влияют на структуру лесов, видовой состав и процессы естественного возобновления, особенно в горных и предгорных лесных поясах. Во многих деградированных лесных районах наблюдались эрозия почвы, снижение плотности лесов и замена ценных древесных видов кустарниками и малоценной растительностью. Поэтому меры по восстановлению должны включать строгую защиту лесных территорий, ограничение выпаса скота, предотвращение незаконной вырубки деревьев и реализацию программ естественного и искусственного лесовосстановления.

Особое внимание было уделено выбору видов деревьев, адаптированных к деградированным и подверженным эрозии условиям. Результаты показывают, что такие виды, как Pinus eldarica, Pinus nigra, береза и груша обыкновенная, демонстрируют высокую адаптивность и благоприятный рост в условиях бедных почв и засушливого климата. Искусственные лесные насаждения, созданные на деградированных склонах, способствуют восстановлению почвы, снижению эрозионных процессов и постепенному восстановлению экологического баланса.

Исследование подчеркивает, что устойчивое лесопользование и восстановление экосистем требуют комплексных экологических подходов, сочетающих лесопосадки, сохранение биоразнообразия, борьбу с эрозией и рациональное использование лесных ресурсов. Внедрение научно обоснованных мер по восстановлению будет способствовать повышению продуктивности лесов, стабилизации горных ландшафтов и долгосрочной экологической устойчивости.

Ключевые слова: *лесные экосистемы, экологическое восстановление, антропогенное воздействие, лесопосадки, продуктивность лесов, эрозия почвы, горные леса, сохранение биоразнообразия.*

Forest ecosystems play an essential role in maintaining ecological balance, protecting biodiversity, preventing soil erosion, and regulating climatic conditions. However, increasing anthropogenic pressure, illegal logging, overgrazing, and irrational land use have caused serious degradation of forest ecosystems in many mountainous regions. The restoration of forest productivity and the conservation of degraded forest landscapes therefore remain among the most important environmental priorities [4,8,9,12].

Anthropogenic impacts significantly alter the composition and structure of forest vegetation. In some cases, these impacts only slightly affect afforestation conditions, while in other situations they lead to severe degradation of forest ecosystems [18,22]. Preventive and restoration measures can partially restore the natural state of forests if timely interventions are implemented. Therefore, degraded forest areas must be strictly protected from harmful external influences. This includes the removal of shrubs and trees that negatively affect forest regeneration, restricting livestock grazing within forest territories, and implementing measures that support natural regeneration processes.

Illegal tree cutting has become one of the major threats to forest ecosystems, especially in mountainous and foothill regions where local populations depend on forest resources. Continuous deforestation accelerates soil erosion and gradually worsens afforestation conditions [24]. Research findings indicate that strict protection of forest boundaries and limitation of anthropogenic impacts contribute significantly to the restoration of degraded forest cover. In many degraded stands, straight-stemmed forests can be re-established through reconstruction activities, including the removal of damaged bush-like trees and the creation of suitable conditions for canopy closure. After approximately 10–15 years, corridors can be established within regenerated stands and valuable tree species can be planted.

On steep mountain slopes affected by erosion, low-value and curved-stemmed trees should be selectively removed while preserving ecologically and economically important species such as oak, alder, and birch. In many south-facing slopes, erosion

has exposed parent rock material and removed fertile soil layers, resulting in extremely dry afforestation conditions. Under such circumstances, natural regeneration occurs very slowly, even after anthropogenic pressures are reduced. Therefore, artificial afforestation measures become necessary in order to accelerate ecosystem recovery [1,6-9].

The selection of suitable tree species is crucial for successful forest restoration. Since many degraded forest soils are poor in mineral nutrients and moisture, valuable but demanding species such as oak, walnut, and chestnut often show low adaptability in these conditions [12-18,23,24]. Consequently, forest restoration programs should prioritize species that are resistant to drought and adapted to poor soils. Research has shown that at elevations of approximately 500–600 m above sea level, particularly on rocky foothill slopes, species such as Eldar pine and Crimean pine produce favorable results. In eroded middle mountain forest belts, mixed pine plantations consisting of Crimean pine and common pine are effective, whereas in upper forest belts, common pine, pear, and birch form stable and productive forest stands.

Artificially established forests on eroded slopes gradually improve soil quality over time. Once soil conditions recover sufficiently, it becomes possible to replace pioneer and resistant tree species with more valuable edificatory species characteristic of natural forest ecosystems. However, forest degradation continues to intensify near settlements due to excessive grazing and uncontrolled wood harvesting. In the southern slope of the Greater Caucasus, many beech forests have been replaced by sparse shrub vegetation. Similar degradation processes are observed in the middle mountain forest belts of the Lesser Caucasus and the Talysh Mountains, where sparse forests dominate around populated areas.

In these regions, restoration measures should combine natural regeneration with scientifically planned afforestation activities [7,11,18]. Mountain meadows, glades, and shrublands located within upper mountain forest belts provide favorable ecological conditions for the expansion of forest vegetation. Therefore, restoration

programs should focus on increasing forest productivity while simultaneously preserving ecological stability and biodiversity.

Overall, the degradation of mountain forests negatively affects ecological regulation processes and disrupts the balance of natural and anthropogenic landscapes. Sustainable forest management strategies aimed at restoration, conservation, and productivity enhancement are therefore essential. Ecological assessment, soil fertility evaluation, and bonitation studies conducted across different forest belts demonstrate that increasing forest productivity is closely connected with both environmental and socio-economic conditions. Effective forest restoration requires integrated management approaches that combine ecological protection, afforestation, erosion control, and rational use of forest resources.

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