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SOIL EROSION AND CONSERVATION STRATEGIES ACROSS CLIMATES WITH A FOCUS ON UZBEKISTAN

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Abstract. *Soil erosion is one of the most challenging threats to agricultural productivity. This study presents a comprehensive literature review focusing on soil erosion types, their driving factors, conservation strategies, and soil productivity restoration. The review analyzes different forms of soil erosion, including water erosion, wind erosion, gully erosion, and human-accelerated erosion, together with the effects of climate change, land-use change, and deforestation. Conservation methods identified in the literature include contour plowing, reforestation, crop rotation, minimum tillage, organic matter management. The findings confirm that restoration of degraded soils is possible but requires integrated and long-term management practices. Although many conservation strategies have proven effective under specific environmental conditions, their successful implementation depends on local soil, climate, and land-use characteristics. Therefore, further researches have to be done to better understand soil erosion and its conservation methods.*

Keywords: *Land degradation, soil erosion, soil conservation, Uzbekistan, agricultural productivity, conservation strategies, contour plowing, soil restoration.*

Annotatsiya. *Tuproq eroziyasi qishloq xo‘jaligi unumdorligi uchun eng qiyin tahdidlardan biridir. Ushbu tadqiqot tuproq eroziyasi turlari, ularning harakatlantiruvchi omillari, tabiatni muhofaza qilish strategiyalari va tuproq unumdorligini tiklashga qaratilgan keng qamrovli adabiyotlar sharhini taqdim etadi. Sharhda suv eroziyasi, shamol eroziyasi, jar eroziyasi va inson tomonidan tezlashtirilgan eroziya kabi tuproq eroziyasining turli shakllari, shuningdek, iqlim o‘zgarishi, yerlardan foydalanish o‘zgarishi va o'rmonlarning kesilishi ta’siri tahlil qilinadi. Adabiyotda aniqlangan tabiatni muhofaza qilish usullari konturli shudgorlash, o‘rmonlarni qayta tiklash, almashlab ekish, minimal ishlov berish, organik moddalarni boshqarishni o‘z ichiga oladi. Topilmalar degradatsiyaga uchragan tuproqlarni tiklash mumkinligini tasdiqlaydi, ammo integratsiyalashgan va uzoq muddatli boshqaruv amaliyotlarini talab qiladi. Ko‘pgina tabiatni muhofaza qilish strategiyalari ma’lum atrof-muhit sharoitlarida samarali ekanligi isbotlangan bo‘lsada, ularni muvaffaqiyatli amalga oshirish mahalliy tuproq, iqlim va yerlardan foydalanish xususiyatlariga bog‘liq. Shuning uchun, tuproq eroziyasi va uni muhofaza qilish usullarini yaxshiroq tushunish uchun qo‘shimcha tadqiqot, izlanishlarni o‘tkazish kerak.*

Kalit so‘zlar: *Yerlarning degradatsiyasi, tuproq eroziyasi, tuproqni muhofaza qilish, O‘zbekiston, qishloq xo‘jaligi unumdorligi, tabiatni muhofaza qilish strategiyalari, konturli shudgorlash, tuproqni tiklash.*

Аннотация. *Эрозия почв представляет собой одну из наиболее серьезных угроз для продуктивности сельского хозяйства. В данном исследовании представлен всесторонний обзор литературы, посвященный видам эрозии почв, факторам, способствующим их развитию, стратегиям охраны почв и восстановлению их продуктивности. В обзоре анализируются различные формы эрозии, включая водную, ветровую и овражную эрозию, а также эрозию, ускоренную антропогенным воздействием, и рассматривается влияние изменения климата, изменений в землепользовании и обезлесения. К числу методов охраны почв, описанных в литературе, относятся контурная вспашка, лесовосстановление, севооборот, минимальная обработка почвы и управление содержанием органического вещества. Результаты исследования подтверждают, что восстановление деградированных почв возможно, однако оно требует применения комплексных и долгосрочных мер управления. Хотя многие стратегии охраны почв доказали свою эффективность в определенных природных условиях, их успешная реализация зависит от местных почвенных и климатических характеристик, а также от особенностей землепользования. В связи с этим необходимы дальнейшие исследования для углубленного понимания процессов эрозии почв и методов их предотвращения.*

Ключевые слова: *деградация земель, эрозия почв, охрана почв, Узбекистан, продуктивность сельского хозяйства, стратегии охраны почв, контурная вспашка, восстановление почв.*

INTRODUCTION

Soil is a fundamental resource for agricultural production, yet the recovery of degraded soil requires a long period of time (Juliev et al., 2024). Agriculture plays a significant role in Uzbekistan's economy, accounting for 17.3% of GDP and 30.9% of the gross value added of small businesses in 2025 (National Statistics Committee of the Republic of Uzbekistan). These figures highlight the importance of sustainable soil management for ensuring agricultural productivity and food security.

Previous studies have examined soil erosion and conservation practices in different regions. Research in Africa described major erosion types and assessment methods (Eric Roose et al., 2008), while studies in South Africa focused on water erosion in duplex soils and conservation measures such as reforestation and drainage (Parwada & Van Tol, 2016). Other studies proposed improved tillage systems for controlling wind and water erosion (Mirzaev et al., 2019), highlighted the effectiveness of plant cover in reducing soil erosion and runoff (Zuazo & Pleguezuelo, 2008), and examined the relationship between soil degradation, climate change, and food security on a global scale (Lal, 2014).

This thesis reviews the major causes of soil erosion and evaluates widely used soil conservation strategies. Based on international research and practical case studies, it discusses approaches such as terracing, contour plowing, cover cropping, crop rotation, agroforestry, windbreaks, vegetation restoration, nutrient and water

management, and no-till farming, emphasizing their potential application for improving soil conservation practices in Uzbekistan.

MYTHOLOGY AND LITERATURE REVIEW

This study adopts a qualitative analytical approach based on secondary data. Scientific articles, books, and statistical reports were systematically reviewed and analyzed to examine soil degradation, soil erosion, and soil conservation strategies under different climatic and environmental conditions. The research is focused on Uzbekistan; however, studies and experiences from other continents and countries were also reviewed to provide a broader understanding of the causes, impacts, and management of soil degradation.

2.1. Studies on soil degradation and erosion

Early studies of erosion (in scope of our research) discuss soil erosion rates and productivity loss for two areas of the United States, the types of erosion including water erosion, wind erosion (H.E. Dregne, 1987). As author states water erosion is more serious problem than wind erosion in both arid and humid regions. In some areas water erosion has reduced soil productivity for over 50 years.

Eric Roose et al. (2008) in his 50 years of research of Africa, examined main problems of soil erosion, and conservation strategies to be done in places. Erosion is highly associated with loss of nutrient loss and carbon sequestration. Restoration of soil: as authors state water and soils are non-renewable resources, if the thin topsoil over a hard calcareous or granitic rock is eroded, it will not be possible to restore the soil in a single lifetime because it takes 1000 to 3000 years to create 10 cm of soil.

It is possible to restore soil productivity, by following these steps:

1. Since eroded soils produce high runoff, the first step is to manage water flow using measures such as stone bunds, vegetative hedges, and basins.
2. Because degraded soils are compact and unstable, they should be deeply plowed and improved with organic matter or calcium carbonate to increase stability.
3. As deeper soil layers have lower biological activity than the humus layer, compost or manure rich in microbes and mycorrhiza should be added to improve nutrient availability.
4. Since degraded soils are nutrient-poor and cannot retain nutrients well, fertilizers should be applied directly to plants when needed rather than relying on the soil to store them.
5. If soil pH is too low (below 5), it should be raised above 5 to reduce aluminium toxicity. (Eric Roose et al., 2008)

2.2 Uzbekistan

The total land area of Uzbekistan is 44.7 hectares with natural pastures - 46.8%, forest lands 8%, and urban and infrastructure areas 34.5%. Arable land constitutes only 4.3 million hectares of which 3.3 million ha. directed to irrigated agriculture. A large area of land in Uzbekistan is affected by degradation and desertification, including strong soil compaction and crust formation (more than 50% of irrigated land), wind erosion (56% of all lands), irrigation erosion (covering 7,603 sq. km of land), soil salinization (47% of the irrigated area), and low organic matter in soils. (Umarov et al., 2025, cited as Eshmatov, 2024).

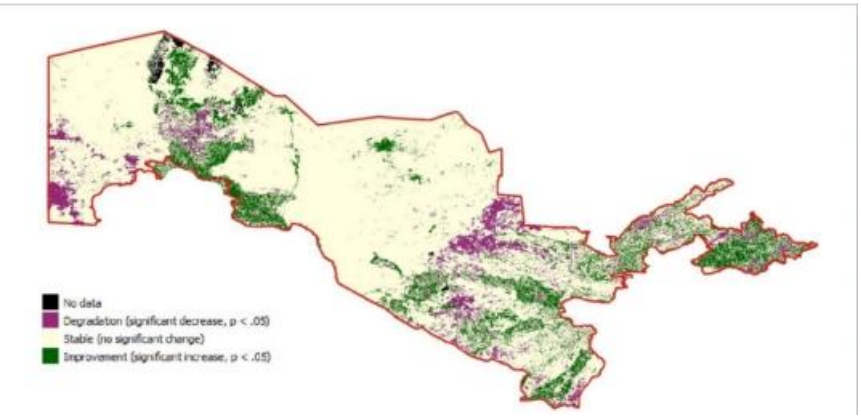

Figure 1. Land degradation trends in Uzbekistan for the period 2010–2020 prepared using the Trends. Earth tool. Source of data: Soil and Agrochemical Research Institute, Tashkent, Uzbekistan. (Umarov et al., 2025)

Mitigation actions in Uzbekistan. Uzbekistan and Kazakhstan together account for around 6 million hectares of the dried bed of the Aral Sea. Of this, about 3.2 million hectares are located in Uzbekistan, with approximately 2.5 million hectares designated for forest plantations. A national program to rehabilitate the Aral Sea region was launched in 2017. By the end of 2024, more than 1.7 million hectares had already been afforested. Plants such as "saxaul" and "tamarisk", which are resistant to salinity, play an important role in reducing the spread of harmful dust and salts into the atmosphere. They also help absorb excess salt from the soil, gradually improving land conditions for agricultural use. In addition, the Forestry Agency of Uzbekistan is actively implementing national greening initiatives. One of the major programs is the "Yashil Makon", launched in 2021. This initiative aims to increase the country's green coverage to 30% by 2030, compared to the current level of about 12%. Under this program, Uzbekistan plans to plant around 200 million trees and shrubs each year, with a total target of 1 billion over five years.(Umarov et al., 2025)

Method and strategies of mitigation recommended in water erosion:

- **Soil protection in the periods when the rainfall is potentially more erosive,** During the high erosive rainfalls good green coverage is effective. (Duarte, 2022)
- **Crop rotations less intensive, according to the soil capacity use, incorporation in the soil the crops stubble,** Crop rotation according to soil capacity and climate condition is necessary for reaching adequate fertility level, leguminous crops are recommended to use. After the harvest, shrubs are recommended to leave for increasing and maintenance of organic matter. (Duarte, 2022)
- **Reduction of soil tillage operations,** minimum tillage is recommended for not destucting soil structure, and this increses breakdown of compost by oxygen. (Duarte, 2022)
- **Contouring crop operations,** field activities such as tillage, when performed along contour lines, create small concavities in the soil. These concavities temporarily hold water and trap soil particles, thereby helping to retain moisture

and reduce runoff, which contributes to increased water availability in the field. (Duarte, 2022). “Contour ploughing mitigates the impacts of floods, storms and landslides on the crops by reducing soil erosion up to 50 percent, controlling runoff water, increasing moisture infiltration and retention and thus enhancing soil quality and composition.” (FAO, 2008)

- **Use of simulation models,** it is considered to effective tool to reproduce a certain process, in this case soil water erosion. As results show no significant relationship was observed between average sediment production and average runoff volume across most basin cells. (Duarte, 2022)
- **Afforestation and sowing grass,** planting trees and grasses is a key method for conserving soil and water in the Loess Plateau. Trees and fruit crops should be planted in gullies, while grasses and shrubs should cover slopes. (Bojie Fu, 1989). Removing vegetation and practicing intensive farming in mountainous areas increases land degradation. (Zuazo & Pleguezuelo, 2008).

III. Discussion

3.1 Erosion types

Water Erosion	Rainfall intensity, soil texture, slope, vegetation cover, land use	Dregne (1987); Duarte (2022); Lal (2012); Bojie Fu (1989)
Wind Erosion	Wind speed, soil moisture, vegetation cover, land surface roughness	Dregne (1987); Mirzaev et al. (2019)
Gully Erosion	Concentrated runoff, slope gradient, soil type (duplex soils), land degradation	Eric Roose, Dazzi et al. (2008); Parwada & Van Tol (2016)
Raindrop (Splash) Erosion	Rainfall erosivity, drop size, soil erodibility, vegetation canopy	Duarte (2022); Zuazo & Pleguezuelo (2008)
Accelerated (Human-induced) Erosion	Deforestation, land-use change, intensive tillage, overgrazing, urbanization	Lal (2012); Zuazo & Pleguezuelo (2008);
Mass Movement (Landslides)	Slope gradient (>15°), soil saturation, vegetation loss, seismic activity	Eric Roose, Dazzi et al. (2008); Bojie Fu (1989)

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3.2 Conservation methods

Contour Ploughing / Contouring	Water erosion, runoff	Duarte (2022); FAO (2008)
Crop Rotation & Cover Cropping	Water erosion, wind erosion, soil degradation	Duarte (2022); Lal (2012)
Reforestation & Vegetation Restoration	Water erosion, wind erosion, gully erosion, mass movement	Parwada & Van Tol (2016); Bojie Fu (1989); Zuazo & Pleguezuelo (2008)
Minimum / Conservation Tillage	Water erosion, wind erosion	Duarte (2022); Lal (2012);
Organic Matter Management	Water erosion, soil degradation	Parwada & Van Tol (2016); Eric Roose et al. (2008);
Engineering & Structural Measures	Gully erosion, water erosion, runoff, mass movement	Eric Roose et al. (2008); Bojie Fu (1989); Parwada & Van Tol (2016)
Land-Use Adjustment	Water erosion, mass movement, accelerated erosion	Bojie Fu (1989); Zuazo & Pleguezuelo (2008)
Soil pH & Fertility Management	Post-erosion soil restoration	Eric Roose et al. (2008); Parwada & Van Tol (2016)
Simulation & Predictive Models	All erosion types (planning/monitoring tool)	Duarte (2022); Duulatov et al. (2019)

** Done by author with assistance of AI tool*

CONCLUSION

The reviewed literature and data indicate that soil erosion remains as one of the important environmental challenges in various geographic continents, caused by natural processes and increased human activities. Water erosion consistently emerges as the dominant threat, while wind erosion, gully erosion, and mass movements pose significant regional concerns. However, a range of conservation methods and strategies have been recommended, including contour ploughing, reforestation, green covering, minimum tillage, and other engineering measures. Admittedly, each method is applied in accordance with local soil type, climate and topographic conditions of certain area. Nevertheless, several gaps in studied articles and data remain. Most of the studies focus on individual regions or single erosion types, limiting cross-regional comparisons. Thus, further studies should be focused on integrated, practical approaches on region-specific fields (areas) against soil erosion, particularly in Uzbekistan.

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