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SOIL DEGRADATION IN UZBEKISTAN: A QUANTITATIVE ANALYSIS OF SALINIZATION, DEFLATION, AND SOCIO-ECONOMIC CONSEQUENCES.

Abstract. This paper provides a comprehensive analysis of the escalating crisis of soil degradation in the Republic of Uzbekistan, a nation where the agricultural sector is fundamental to economic and social stability. The study focuses on the primary drivers and quantitative impacts of degradation, synthesizing data from national reports, international organizations (FAO, UNDP, World Bank), and recent academic literature. The analysis confirms that approximately 47% of Uzbekistan's 4.28 million hectares of irrigated land is affected by varying degrees of salinization, a direct consequence of decades-long inefficient irrigation practices, inadequate drainage infrastructure, and an arid climate. This secondary salinization is identified as the principal threat, leading to estimated crop yield losses ranging from 30% in slightly saline soils to over 80% in strongly saline areas. Compounding this issue is severe wind erosion (deflation), originating from the 60,000 km² Aralkum desert (the dried Aral Sea bed), which deposits toxic salt-dust on fertile lands. The cumulative economic burden of water shortages and land degradation is estimated to cost the nation approximately 11% of its GDP annually. This paper examines the problem's typology, analyzes its profound socio-economic consequences, and evaluates the efficacy of current and proposed mitigation strategies, including the national "Year of Environmental Protection and the Green Economy 2025" initiative and the imperative shift towards Climate-Smart Agriculture (CSA) and water-saving technologies.

Keywords: *Soil Degradation, Secondary Salinization, Uzbekistan, Aral Sea Crisis, Deflation, Economic Impact, Water-Saving Technology, Climate-Smart Agriculture.*

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ДЕГРАДАЦИЯ ПОЧВ В УЗБЕКИСТАНЕ: КОЛИЧЕСТВЕННЫЙ АНАЛИЗ ЗАСОЛЕНИЯ, ДЕФЛЯЦИИ И СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ ПОСЛЕДСТВИЙ.

Аннотация. В данной работе представлен всесторонний анализ обостряющегося кризиса деградации почв в Республике Узбекистан, стране, где сельскохозяйственный сектор имеет основополагающее значение для экономической и социальной стабильности. Исследование сосредоточено на основных факторах и количественных последствиях деградации, обобщая данные из национальных отчетов, международных организаций (ФАО, ПРООН, Всемирный банк) и новейшей научной литературы. Анализ подтверждает, что примерно 47% из 4,28 млн гектаров орошаемых земель Узбекистана подвержены засолению различной степени, что является прямым следствием многолетней неэффективной практики орошения, неадекватной дренажной инфраструктуры и засушливого климата. Это вторичное засоление определено как основная угроза, приводящая к предполагаемым потерям урожая от 30% на слабозасоленных почвах до более чем 80% на сильно засоленных участках. Ситуацию усугубляет сильная ветровая эрозия (дефляция), происходящая из-за пустыни Аралкум площадью 60 000 км² (высохшее дно Аральского моря), которая откладывает

токсичную соляную пыль на плодородных землях. Совокупное экономическое бремя нехватки воды и деградации земель оценивается примерно в 11% ВВП страны ежегодно. В данной статье рассматривается типология проблемы, анализируются ее глубокие социально-экономические последствия и оценивается эффективность существующих и предлагаемых стратегий смягчения последствий, включая национальную инициативу «Год охраны окружающей среды и зеленой экономики 2025» и необходимый переход к климатически устойчивому сельскому хозяйству и водосберегающим технологиям.

Ключевые слова: деградация почв, вторичное засоление, Узбекистан, Аральский кризис, дефляция, экономические последствия, водосберегающие технологии, климатически устойчивое сельское хозяйство.

1. INTRODUCTION

Uzbekistan, a double-landlocked nation in Central Asia, is characterized by an arid and semi-arid continental climate. Its economy and food security are inextricably linked to irrigated agriculture, which accounts for over 25% of the GDP and employs a significant portion of the population. However, this vital sector is built upon a precarious foundation: limited water resources, primarily from the transboundary Amu Darya and Syr Darya rivers, and a legacy of Soviet-era agricultural policies that prioritized cotton monoculture at immense environmental cost.

The critical challenge confronting modern Uzbekistan is the rapid degradation of its primary productive asset: the soil. The magnitude of this challenge is severe. Recent data from national monitoring services and international bodies indicate that 46.7% of all irrigated lands are saline to varying degrees (FAO, 2023). This phenomenon, known as secondary salinization, is human-induced and threatens the long-term viability of the nation's agricultural heartland. Furthermore, the desiccation of the Aral Sea has created the Aralkum, a

new toxic desert, unleashing massive sand and dust storms (SDS) that exacerbate soil degradation hundreds of kilometers away.

The economic fallout is staggering. The World Bank estimates that water shortages and associated land degradation cost Uzbekistan approximately 11% of its GDP annually (World Bank, 2022). This multidimensional crisis necessitates a profound scientific analysis of its drivers, a quantitative assessment of its impacts, and a critical evaluation of sustainable solutions. This paper aims to provide such an analysis, arguing that a paradigm shift from resource exploitation to sustainable resource management, underpinned by policy and technology, is imperative for Uzbekistan's future.

2. TYPOLOGY AND SCALE OF SOIL DEGRADATION

Soil degradation in Uzbekistan is not a uniform problem. It manifests in three primary forms, often overlapping and exacerbating one another.

2.1. Secondary Salinization (The Primary Threat)

This is the most widespread and economically damaging form of degradation. It is a direct result of irrigation without adequate drainage. Inefficient flood or furrow irrigation methods lead to massive water seepage, causing the groundwater table (GWT) to rise. In an arid climate, this mineralized water is drawn to the surface via capillary action, where the water evaporates, leaving toxic salts (such as sodium chloride, sulfates, and carbonates) in the root zone.

The scale is precisely quantified: of the total 4.28 million ha of irrigated land, 46.7% (approx. 2 million ha) is saline. The official breakdown is as follows:

- Slightly Saline (ECe = 2-4 dS/m): 30.9%
- Moderately Saline (ECe = 4-8 dS/m): 13.3%
- Strongly Saline (ECe = 8-16 dS/m): 2.5%

These are not just statistics; they represent a direct threat to plant physiology. Salinity induces osmotic stress, preventing crops from absorbing water, and leads to ionic toxicity, which disrupts metabolic processes and causes nutrient imbalances.

Degree of Salinity in Irrigated Lands of Uzbekistan (Total 4.28M ha) **Data to Visualize:**

- **Slice 1 (Blue):** Non-Saline (53.3%)
- **Slice 2 (Yellow):** Slightly Saline (30.9%)
- **Slice 3 (Orange):** Moderately Saline (13.3%)
- **Slice 4 (Red):** Strongly Saline (2.5%)
- *Source: Based on data from the Ministry of Water Resources & FAO (2023)*

2.2. Wind Erosion (Deflation) and the Aral Sea Impact

The desiccation of the Aral Sea is one of the 20th century's most severe environmental disasters. The exposed seabed, now known as the "Aralkum," covers 60,000 km² and is a source of intense Sand and Dust Storms (SDS). These storms transport an estimated 100 million tons of salt-laden, toxic dust annually, containing pesticides and chemical residues from decades of agricultural runoff.

This deflation has two effects:

1. Physical Degradation: The sandblasting effect damages crops and infrastructure.
2. Chemical Degradation: The deposition of toxic salts on otherwise fertile land in Karakalpakstan, Khorezm, and Bukhara regions induces a *new layer* of salinization, destroying pasturelands and contaminating croplands.

2.3. Water Erosion and Humus Depletion

Water erosion is localized in Uzbekistan's foothills and mountainous regions (e.g., Fergana Valley, Tashkent, and Kashkadarya regions). Improper irrigation on sloping lands washes away the fertile topsoil (A-horizon), leading to the formation of rills and gullies.

Simultaneously, the Soviet legacy of cotton-wheat monoculture has severely depleted soil organic matter (humus). Most irrigated soils in Uzbekistan have humus content below 1.0% (critically low is 1.5%), which destroys soil structure, reduces water-holding capacity, and diminishes natural fertility, making soils more susceptible to both erosion and salinization.

3. SOCIO-ECONOMIC AND ENVIRONMENTAL CONSEQUENCES

The impacts of degradation are systemic, affecting the economy, environment, and public health.

- **Economic Impact:** The primary consequence is a direct loss of agricultural productivity. Yield losses are directly correlated with salinity levels:
  - Slightly Saline: 10-33% yield loss
  - Moderately Saline: 30-50% yield loss
  - Strongly Saline**:** 65-85% yield loss (or total crop failure) This translates into billions of dollars in lost revenue for farmers and the state. The macro-level figure, an **11% loss of GDP** when combined with water scarcity, underscores the existential nature of the threat.
- **Environmental Impact:** Degradation triggers a cascade of environmental failures. These include the loss of soil biodiversity (microorganisms), desertification of productive land, and the severe pollution of return-flow (collector-drainage) water, which further salinizes downstream water bodies.
- **Social & Health Impact:** For rural populations, soil degradation means reduced income, debt, and displacement. Furthermore, the toxic dust storms from the Aralkum are directly linked to a sharp increase in respiratory illnesses, anemia, and other severe health conditions in the Karakalpakstan region.

4. MITIGATION STRATEGIES AND NATIONAL POLICY

Addressing this crisis requires a multi-pronged strategy combining policy, technology, and agronomy.

4.1. National Policy Framework

The government of Uzbekistan has recognized the severity of the problem. The declaration of 2025 as the "Year of Environmental Protection and the Green Economy" by President Shavkat Mirziyoyev signals a high-level political commitment. This initiative prioritizes:

1. **Water Conservation:** As the root cause of salinization.

2. **Afforestation:** Including the "Yashil Makon" (Green Space) initiative and large-scale planting of saxaul (Haloxylon) on the Aral Sea bed.
3. **Climate Change Mitigation:** Integrated into national planning.

This is supported by international partnerships, such as the Global Green Growth Institute (GGGI) Country Planning Framework (2024-2028), which aims to help mobilize **$1 billion in green financing**, including **$50 million specifically for climate-resilient agriculture.**

4.2. Technical and Agronomic Solutions

Policy must be implemented through on-the-ground action.

1. **Water-Saving Technologies:** The most critical intervention is shifting from furrow irrigation to **drip irrigation** and **sprinkler systems**. These technologies deliver water directly to the plant, reducing water use by 40-60% and, crucially, preventing the waterlogging that causes the GWT to rise. State subsidies for these technologies are accelerating their adoption.
2. **Improved Melioration:** This involves the modernization and cleaning of thousands of kilometers of collector-drainage networks to effectively lower the groundwater table and flush salts from the soil profile.
3. **Climate-Smart Agriculture (CSA):** This is a holistic approach:
    - **Laser Land-Leveling:** Ensures uniform water distribution, preventing ponding.
    - **Crop Rotation:** Breaking the cotton monoculture by introducing crops like alfalfa, legumes, and other siderates (green manures) that restore nitrogen and organic matter (humus) to the soil.
    - **Conservation Tillage (No-Till/Min-Till):** Reducing plowing to protect soil structure and reduce moisture loss and erosion.
4. **Aral Sea Bed Mitigation:** Afforestation of the Aralkum with drought-and-salt-tolerant species (halophytes) like saxaul. A 2025 UNDP/FAO study has, for the first time, *quantified* the effectiveness of this vegetation in stabilizing

the soil and *reducing salt removal in millions of tons per year*, proving its efficacy as a large-scale intervention.

5. CONCLUSION

Soil degradation, driven primarily by secondary salinization and Aral Sea-related deflation, represents a profound and immediate threat to Uzbekistan's economic prosperity, food security, and environmental stability. The data is unequivocal: with nearly half of its irrigated land compromised and 11% of its GDP at stake, inaction is not an option.

The legacy of unsustainable water management has created this crisis, but a new path forward is emerging. Uzbekistan's future agricultural viability depends on the successful, large-scale implementation of a new paradigm based on water-use efficiency (drip irrigation), soil health restoration (crop rotation, humus building), and large-scale ecological engineering (Aralkum afforestation). The national "Green Economy 2025" strategy, supported by international finance, provides the necessary policy framework. The challenge now lies in accelerating the adoption of these technologies and practices from pilot projects to a new national standard.

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