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**ASSESSMENT OF ENZYMATIC ACTIVITY AND ECOLOGICAL  
STATUS OF GRAY SOILS IN KAMASHI DISTRICT UNDER ARID CLIMATE  
AND ANTHROPOGENIC PRESSURE**

*Uzoqov Zafar Zoirovich*

*Head of the Department of Ecology and Environmental Protection,  
Qarshi State Technical University, PhD in Biological Sciences, Associate Professor*

*Safar Anvar Abdinazarovich*

*Assistant of the Department of Ecology and Environmental Protection,  
Qarshi State Technical University*

**Abstract:** Soil degradation in arid and semi-arid ecosystems of Central Asia represents a serious threat to soil ecological stability and sustainable agricultural development. This study evaluates the physicochemical and biochemical properties of gray soils in irrigated plains, foothill (adir), and mountain foothill landscapes of Kamashi District, Kashkadarya Region, Uzbekistan. The research area is characterized by significant anthropogenic pressure associated with irrigated agriculture, rainfed farming, intensive grazing, and erosion processes. Field investigations were conducted along an altitudinal gradient of 400–1200 m during 2024–2025. Soil quality was assessed using enzymatic indicators, particularly catalase and invertase activities, along with pH, salinity, humus content, and aggregate stability. The results revealed alkaline soil conditions (pH 8.5–9.5) and weak to moderate salinization in irrigated areas, accompanied by a decline in enzymatic activity. In contrast, higher biological stability was observed in relatively undisturbed foothill ecosystems. A strong positive correlation was identified between humus content and the integrated soil biological quality index ( $R^2 = 0.89$ ), confirming the high sensitivity of enzymatic indicators for early detection of soil degradation processes.

**Keywords:** gray soils, arid ecosystems, soil enzymes, catalase, invertase, salinity, bioindicators, soil degradation.

**ОЦЕНКА ФЕРМЕНТАТИВНОЙ АКТИВНОСТИ И  
ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ СЕРОЗЁМНЫХ ПОЧВ  
КАМАШИНСКОГО РАЙОНА В УСЛОВИЯХ АРИДНОГО КЛИМАТА И  
АНТРОПОГЕННОЙ НАГРУЗКИ**

*Узоков Зафар Зоирович*

*Заведующий кафедрой «Экология и охрана окружающей среды»  
Каршинского государственного технического университета,  
доктор философии (PhD) по биологическим наукам, доцент*

*Сафар Анвар Абдиназарович*

*Ассистент кафедры «Экология и охрана окружающей среды»  
Каршинского государственного технического университета*

**Аннотация:** Деградация почв в аридных и полуаридных экосистемах Центральной Азии представляет серьёзную угрозу экологической устойчивости почв и устойчивому развитию сельского хозяйства. В данном исследовании проведена оценка физико-химических и биохимических свойств серозёмов орошаемых равнин, адырных и предгорных ландшафтов Камашинского района Кашкадарьинской области Республики Узбекистан. Исследуемая территория характеризуется значительной антропогенной нагрузкой, связанной с орошаемым земледелием, богарным земледелием, интенсивным выпасом скота и эрозионными процессами. Полевые исследования проводились вдоль высотного градиента 400–1200 м в 2024–2025 гг. Качество почв оценивалось с использованием ферментативных показателей, в частности активности каталазы и инвертазы, а также показателей pH, засоленности, содержания

гумуса и устойчивости почвенных агрегатов. Результаты показали щелочную реакцию почвенной среды (рН 8,5–9,5) и слабую либо умеренную степень засоления на орошаемых территориях, сопровождающуюся снижением ферментативной активности. В то же время более высокая биологическая устойчивость была выявлена в относительно ненарушенных предгорных экосистемах. Установлена сильная положительная корреляционная связь между содержанием гумуса и интегральным индексом биологического качества почв ( $R^2 = 0,89$ ), что подтверждает высокую чувствительность ферментативных показателей для раннего выявления процессов деградации почв.

**Ключевые слова:** серозёмы, аридные экосистемы, почвенные ферменты, каталаза, инвертаза, засоление, биоиндикаторы, деградация почв.

**Introduction.** Soil ecological stability in mountain and foothill ecosystems plays a crucial role in ensuring environmental resilience under global climate change conditions (Doran & Parkin, 2024; Toderich et al., 2024). The Kamashi District of Uzbekistan represents a vertically zoned agroecological system extending from desert-steppe plains to the western foothills of the Gissar Mountain Range. The soil cover is mainly represented by light gray, typical gray, and dark gray soils, reflecting strong dependence on relief and climatic conditions.

In recent decades, increasing anthropogenic pressure has intensified soil degradation processes. In irrigated lowland areas, soil pH values have increased up to 8.9, accompanied by weak to moderate salinization, indicating the development of secondary salt accumulation processes. These conditions negatively affect microbial activity and slow down organic matter decomposition (Haziiev, 2020).

In foothill regions, erosion processes and rainfed agriculture have led to soil structure degradation and humus depletion. In mountain foothill pastures, localized degradation is observed due to intensive grazing pressure (Garcia-Ruiz et al., 2025).

Therefore, catalase and invertase enzymes are considered important bioindicators for early diagnosis of soil condition in arid ecosystems (Markert et al., 2023).

## Materials and Methods

### 2.1 Study area and sampling design

Field investigations and soil sampling were conducted during 2024–2025 across main landscape zones of Kamashi District, differing in altitude gradient and anthropogenic pressure:

**1. Lowland zone (425 m a.s.l.)** – intensively irrigated cultivated light gray soils

**2. Foothill zone (750 m a.s.l., Qiziltepa and Changak areas)** – rainfed agricultural lands affected by erosion, typical gray soils

**3. Mountain foothill zone (1100 m a.s.l.)** – natural pasture ecosystems, including both low and high grazing pressure areas, dark gray soils

Soil samples were collected in spring, summer, and autumn from depths of 0–30 cm and 30–50 cm using a quadrat (envelope) sampling method.

### 2.2 Biochemical and physicochemical analyses

Soil analyses were performed in certified analytical laboratories using standard methods:

Soil pH was determined by a potentiometric method in a soil–water suspension (1:2.5 ratio) using a calibrated glass electrode pH meter.

Salinity was determined from aqueous soil extracts (1:5 soil-to-water ratio) by measuring electrical conductivity after filtration.

Humus content was measured using the Tyurin method modified by Simakov, based on wet oxidation with potassium dichromate under acidic conditions.

Catalase activity was determined using a gasometric method, based on the decomposition of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) and measurement of released oxygen volume ( $\text{cm}^3 \text{O}_2 \text{g}^{-1} \text{soil min}^{-1}$ ).

Invertase activity was determined using the Khaziev method, based on 24-hour incubation of soil samples with sucrose solution and subsequent spectrophotometric determination of glucose ( $\text{mg glucose g}^{-1} \text{soil 24 h}^{-1}$ ).

Aggregate stability was assessed using the Savvinov wet-sieving method.

## Results

Significant differences in soil physicochemical and enzymatic properties were observed along the altitudinal gradient (Table 1).

Table 1. Physicochemical and enzymatic properties of gray soils (0–30 cm layer)

Zo ne	Soi l type	H umus (%)	p H	Salin ity	Wa ter-stable aggregates (%)	C atalase	In vertase
<b>Irri gated lowland</b>	Cul tivated light gray soil	1. 25±0.08	8 .9	Wea k-moderate salinity	34. 2	3. 45±0.12	8. 12±0.34
<b>Fo thill (rainfed)</b>	Ero ded typical gray soil	0. 98±0.05	7 .8	Wea k salinity	18. 5	2. 10±0.09	4. 22±0.18
<b>Fo thill natural</b>	Dar k gray soil (reference)	2. 84±0.15	7 .3	Non- saline	56. 8	5. 88±0.22	1 6.45±0.62
<b>Fo thill pasture- degraded</b>	Dar k gray soil	1. 62±0.11	7 .5	Wea k salinity	28. 1	3. 15±0.14	7. 30±0.29

The highest humus content and enzymatic activity were recorded in undisturbed foothill soils, while the lowest values were observed in eroded rainfed areas.

Seasonal dynamics showed maximum enzymatic activity during spring (April–May), associated with optimal hydrothermal conditions and active vegetation growth. During summer, invertase activity decreased by 60–70% in all zones, while catalase remained relatively more stable.

The most pronounced degradation differences were observed in the foothill rainfed zone, where soil erosion reduced invertase activity by 3.9 times and catalase activity by 2.8 times compared to the reference site.

**Discussion.** The results demonstrate that foothill gray soils in Kamashi District have relatively low ecological buffering capacity against mechanical disturbance and erosion processes. Soil salinity was identified as one of the key factors contributing to reduced enzymatic activity.

Increased salt concentration in soil solution creates osmotic stress for microorganisms, thereby reducing metabolic activity and enzyme synthesis. As reported by Haziev (2020), increasing salinity significantly slows down microbial processes and reduces enzymatic activity in soils. Similar observations have been reported by Garcia-Ruiz et al. (2025), who demonstrated that soil enzyme activity decreases significantly under salinization stress in semi-arid environments.

In rainfed foothill zones, reduced water-stable aggregates (18.5%) were closely associated with decreased hydrolase activity. Invertase, being an extracellular enzyme, is strongly adsorbed onto soil colloids and is easily removed together with fine particles during heavy rainfall events, further reducing enzymatic activity.

Comparison between natural and heavily grazed foothill pastures revealed that increased grazing pressure leads to soil compaction, reduced aeration, and decreased aerobic microbial activity. Reduced catalase activity reflects increased oxidative stress and disruption of microbial communities.

Consistent with global studies (Doran & Parkin, 2024; Garcia-Ruiz et al., 2025), soil biological indicators respond more rapidly to degradation processes than physicochemical properties. A strong linear relationship was observed between humus content (X) and the integrated soil biological quality index (Y):

$$Y = 4.12X + 1.85 (R^2 = 0.89)$$

### **Conclusions**

1. Irrigated soils exhibited alkaline conditions (pH 8.5–9.5) and weak to moderate salinization, resulting in reduced microbial and enzymatic activity.

2. Erosion processes in rainfed foothill areas significantly reduced humus content and invertase activity.

3. Natural foothill soils demonstrated high humus content and near-neutral pH, ensuring high biological stability.

4. Enzymatic indicators are highly sensitive tools for early detection of soil degradation in arid ecosystems.

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