BIODIAGNOSTICS IN ENVIRONMENTAL ASSESSMENT OF DEGRADED ARID SOILS

L.A.Gafurova,[1] D.A.Kadirova,[2] M.A.Mazirov, [3] O.Kh.Ergasheva[1]
[1]National University of Uzbekistan named after Mirzo Ulugbek
[2]Tashent State Agrarian University,
[3]Russian State Agrarian University named after K. Timiryazev

https://doi.org/10.5281/zenodo.8353413

Abstract. *The article presents the results of studies on a comprehensive assessment of degraded arid soils, spread in the conditions of vertical and horizontal zoning of soil formations. The changes in biological properties under the influence of degradation processes, the changes in distribution, the number of groups of microorganisms and biochemical activity are shown. It provides criteria for biodiagnostics, which make it possible to assess the degree of general biological activity based on the values of the Integral Index of the Ecological and Biological State of Soils (IIEBSS).*

Keywords: *biological activity, biodiagnostics, arid soils, integral index of the ecological and biological state of soils, soil degradation*

Аннотация. *В статье приведены результаты исследований по комплексной оценке деградированных аридных почв, распространенных в условиях вертикальной и горизонтальной зональности почвообразований, показаны изменения биологических свойств под влиянием деградационных процессов, изменения распространения, количества групп микроорганизмов и биохимической активности, приведены критерии биодиагностики, которые представили возможность оценке степени общей биологическое активности на основе значений интегрального показателя эколого-биологического состояния почв (ИПЭБСП).*

Ключевые слова: *биологическая активность, биодиагностика, аридные почвы, интегральный показатель эколого-биологического состояния почв, деградация почв*

A wide range of activities is being conducted in the Republic of Uzbekistan to maintain a sustainable level of soil fertility, to forecast and create the conditions necessary for the growth and development of crops, rational use of land resources. In order to implement the tasks defined in the Decrees of the President of the Republic of Uzbekistan dated October 4, 2019 - No. 4477 "On approval of the strategy for the transition of the Republic of Uzbekistan to a green economy for 2019-2030" and PD-277 dated October 10, 2022 " On measures to create an effective system to combat land degradation" and other relevant regulatory documents, one of the important tasks is the introduction of innovative environmentally friendly technologies and approaches to adapt the agro-sphere to climate change, improve and protect natural resources, ensure food and environmental security.

In this regard, the regulation and optimization of biological processes occurring in soil play an important role in the search for a scientifically-based practical solution to problems aimed at increasing the efficiency of the use of degraded lands and protecting soil cover, obtaining environmentally friendly and high-quality agricultural products in a "green economy" under conditions of climate change.

Modern approaches to the environmental assessment of the quality of soil resources should be focused on biological indices. Chemical properties are of limited importance and can mainly reflect the amount of macro- and micro-nutrients, the absorption capacity of soils, environmental pollutants, etc. At the same time, modern approaches to characterizing the ecological state of soils should be based on the biotic concept of soil formation, the use of soil organisms in the assessment, biodiagnostics, and bioindication of negative impacts on the environment (degradation, salinization, erosion, and soil pollution) [1, 2, 4, 10].

The aim of the research is a comprehensive systematic approach to the study of the biological activity of arid soils, an assessment of their overall biological activity based on the identification of integral indices of the ecological and biological state of soils, and the development of criteria for soil biodiagnostics.

The object of the research was the arid soils of southern Uzbekistan (on the example of the soils of the Surkhan-Sherabad valley), common in the foothills and mountains and in the desert zone of the region.

Research methods. The study used profile-genetic, comparative-geographical, chemical-analytical, and biological methods. The analysis was performed according to the guidelines "Methods of soil enzymology" [8], "Biological diagnostics and indication of soils: methodology and research methods" [5, 6], "Microbiology and biochemistry of soils" [5]. Accounting for microorganisms grown on liquid media was made on the basis of the McCready table. Correlations between diagnostic indicators of soil fertility and biological activity were determined using *the Statgraphics Centure XVII program. The statistical processing was performed by the Balanced Anova (BAOV) method using the Irristat program.*

Research results. The morphogenetic features of the studied arid soils showed their dependence on the features of the relief and climate, soil-forming rocks, groundwater depth, vegetation, and the geographic distribution of soils. In the mechanical composition of soils, there are mainly light and medium loamy, in some places heavy loamy, sandy loamy, sandy, and clayey soils. The physical properties of soils change depending on the mechanical composition, humus covering, irrigation age, the degree of eroding of foothills and mountain soils, and soil salinization in the desert zone. Agrochemical indicators were characterized by a relatively high content of humus (1.2-4.6%) in soils of vertical zoning compared to soils of horizontal zoning (0.4-1.0%). According to the availability of mobile phosphorus and exchangeable potassium, the soils are mainly classified as very low, low, medium, and, very rarely, as highly rich soils. According to the degree of salinity, they ranged from non-saline and slightly saline soils to highly saline soils and solonchaks. According to the type of salinity, they belong to chloride-sulfate and sulfate types. The content of CO_2 carbonates varied on average from 4.25 to11.1%, and their distribution mainly depended on the degree of erosion, salinity, and the age of soil irrigation.

Depending on the geographical location of types and subtypes of soils, genetic characteristics, and availability of organic matter in the region, the distribution and quantitative changes in the studied groups of microorganisms differed (Table 1).

In the mountain brown and irrigated soils of the serozem belt, the proportion of ammonifiers prevailed, in the soils of the desert zones, an increase in the proportion of actinomycetes (which are able to develop under unfavorable conditions) and butyric acid bacteria (developing under anaerobic conditions) was observed; this can be explained by the succession of microorganisms, that is, soil salinity has a strong influence on the development of bacteria and fungi, as a result, their number is sharply reduced, and this creates a more favorable environment for the development of actinomycetes and butyric acid bacteria. Other groups of microorganisms in all types of soils were found in smaller proportions.

Table 1

The number of microorganisms in mountain brown and sierozem soils of the Surkhan-Sherabad valley (thousand/g of soil)

Depth, cm	Ammoni fiers	Fungi	Actino mycete s	Nitrifiers	Nitrogen fixers	Aerobic cellulose-decomposing microorganisms	Butyric acid bacteria
Mountain- brown typical soils							
0-15	3900	284	875	95	200	40	30
15-30	2270	175	670	40	115	25	16.5
30-50	1580	120	495	25	75	11	9
50-70	700	53	264	9	30	6	4
Dark serozem soils, developed on loess deposits							
0-15	1040	51	110	15	30	9	11
15-30	800	30	64	11	16	4	7.5
30-50	355	19	35	6.5	7.5	1.4	4.5
50-70	197	13	20	2.5	3	-	2
Old-irrigated meadow soils							
0-15	2605	128	650	45	75	40	35
15-30	2070	87	434	30	45	25	20
30-50	1425	58	296	20	25	16.5	14
50-70	1061	37	143	11.5	9.5	9	9
Newly irrigated typical serozem soils							
0-15	884	44	491	9.5	15	11.5	4.5
15-30	501	30	360	6.5	10	6.5	3
30-50	401	22	218	3	6.5	3.0	1.5
50-70	254	12	110	1.4	3	1.5	0.6

The distribution of the number of certain groups of microorganisms along the profile of irrigated soils of the sierozem belt varies depending on their irrigation age. In the old-irrigated soils, a greater number of microorganisms was observed than in the newly irrigated and newly developed soils. This pattern can be explained by the fact that microorganisms penetrate into the deep layers of old-irrigated soils due to the good supply of nutrients as a result of the long-term use of organic and mineral fertilizers.

According to the results of studies it was observed that microorganisms developed weaker in irrigated soils of desert zones due to different degrees of salinity, low provision with humus and nutrient elements, and strong soil compaction. It was revealed that all groups of microorganisms were found in very small quantities even in the upper layers of irrigated sierozem-brown, takyr-meadow, meadow desert-sandy and meadow-desert soils and in the lower layers some groups were not met at all (Table 2).

Changes in the main agrochemical, agrophysical, and microbiological properties of the studied soils due to degradation processes are also reflected in the activity of enzymes.

Invertase, which catalyzes the reactions of hydrolytic cleavage of sucrose, reflects the level of soil fertility and biological activity. Therefore, the activity of invertase in connection with the provision of soils with organic substances varies in the upper layer of foothill and mountain soils within 1.80-23.2, in irrigated soils of the serozem belt – within 2.45-7.10, and in soils of the desert zone - within 1, 28-3.27 mg of glucose.

The activity of phosphatase in soil depends on the content of organic and mineral forms of phosphorus; in the upper layer of foothill and mountain soils it is 0.70-7.20 mg per 100 g of soil, in irrigated soils of the serozem zone, it is 1.80-3.20 mg, and in the desert zone - 0.50-1.30 mg of P_2O_5.

Table 2

The number of microorganisms in irrigated soils of the desert zone of the Surkhan-Sherabad valley (thousand/g of soil)

Depth, cm	Ammonifiers	Fungi	Actinomycetes	Nitrifiers	Nitrogen fixers	Aerobic cellulose-decomposing microorganisms	Butyric acid bacteria
Irrigated takyr-meadow soils							
0-15	1060	81	880	11.5	11	10	20
15-30	705	46	588	7	9	6	10
30-50	304	27	343	3.5	3.5	3.5	6.5
50-70	120	13	128	1.5	2	1.5	2.5
Old-irrigated meadow soils							
0-15	1890	150	1390	30	45	40	65
15-30	1380	102	884	16.5	25	20	30
30-50	810	84	626	9	11.5	10	16.5
50-70	405	55	376	4	7.5	4.5	9
Newly irrigated seirozem -brown soils							
0-15	485	13	550	2	2.5	3	4
15-30	170	9	330	0.7	1.5	1.6	2.5
30-50	80	5	214	0.3	0.6	1	1.1
50-70	40	3	110	-	0.1	0.1	0.1
Old-irrigated meadow-takyr soils							
0-15	910	71	768	9.5	11.5	10	16
15-30	580	38	593	4.5	7.5	7	10
30-50	260	16	236	2.5	4	3.5	6.5
50-70	101	11	120	0.9	1.6	1.5	3
Irrigated meadow desert-sandy soils							
0-15	500	14	563	2.0	4.5	2.5	3.5
15-30	201	8	336	0.6	2.5	1.4	1.2
30-50	82	6	118	0.1	1.2	0.7	0.9
50-70	41	2	81	-	0.3	0.3	0.3

The activity of urease, which catalyzes the hydrolysis of urea in soil to ammonia and carbon dioxide, in the upper layer of mountain and foothill soils was 1.14-5.72 mg NH_3 per 10 g of soil, in irrigated soils of the sierozem belt, it was 1.12-4.70 and in soils of the desert belt, it was 0.16-0.69 mg of NH_3.

The activity of catalase in the upper layer of mountainous and foothill soils was 0.98-15.4 ml of O_2, in irrigated soils of the sierozem belt - 3.20-5.04 ml of O_2, and in soils of the desert zone

- 1.9-4.3 ml of O_2 in 100g of soil. The low activity of catalase in desert soils testified to the accumulation of H_2O_2 in soil, which is a substance harmful to living organisms.

Phenol oxidase enzymes realize redox reactions that characterize the direction of the decay-synthesis processes of humic substances in soil, and the humification coefficient can be calculated from their ratio. Peroxidase activity in the upper layer of mountain and foothill soils was 1.34-10.2, in irrigated soils of the sierozem belt - 1.30-4.23, and in soils of the desert zone - 2.60-3.29 mg of purpurgalin in 100 g of soil. The activity of polyphenol oxidase varies in the upper layer of mountainous and foothill soils within 1.10-11.4, in irrigated soils of the sierozem belt within 1.30-4.23 and in desert soils, it ranges from 1.80 to 5.80 mg of purpurgalin per 100 g of soil. In the studied soils, the humification coefficient ranged from 0.6 to 2.3.

Enzyme activity was mainly manifested in the upper layers – the most biologically active ones. However, there was a slight increase in catalase activity in the lower layers depending on the amount of carbonates in soil. According to the soil profile, the activity of the studied enzymes decreased more smoothly than the number of soil microorganisms.

According to the total activity of enzymes, an increase in the proportion of oxidase enzymes in soils of the region compared to hydrolases was observed, which, on the one hand, was explained by the dry climate of the area under study, and, on the other hand, by the activation of enzymes of the oxidoreductase class with an improvement in the aeration process as a result of the cultivation of the arable horizon.

Soil respiration is a complex biochemical process, the release of CO_2 varies widely depending on a number of factors, including the content of organic matter in soil, the chemical and physical properties of soils, the number of microorganisms, and hydrothermal conditions; in mountainous and foothill soils, it fluctuated within 3.6-11.2, in irrigated soils of the sierozem belt – within 3.2-8.1, in soils of the desert zone – within 2.2-6.0 mg of CO_2 per 10 g of soil. It should be noted that the release of CO_2 also increased significantly in the lower carbonate layers (12.6-16.7 mg of CO_2 per 10 g of soil); this is especially pronounced in the southern exposure of mountain brown carbonate soils. It was noted that the intensity of respiration in irrigated soils of desert zones is much weaker than in the soils of mountainous regions and sierozem belt.

It is known that the biological diagnostics of soil makes it possible to determine the nature and extent of the impact of degradation on the soil cover and to have an idea of the changes occurring in the soil composition. However, this requires to determine a single indicator to assess how much the overall biological activity has changed. For this purpose, integrated index of the ecological and biological state of soils (IIEBSS), proposed by K.Sh. Kazeev et al. [7], are effectively used in soil-ecological and geographical studies. This technique allows us to sum up relative values of various indicators due to the difficulty of comparing these indicators given in different units.

In this regard, informative indices of the biological activity of soils were used for the biodiagnostics of soils in the area under study; these indices include humus content and the number of ecological and trophic groups of microflora, the activity of redox and hydrolytic enzymes, and the intensity of soil respiration.

The degree of general biological activity of the studied soils was estimated from the value of IIEBSS. According to the results of the assessment, it was revealed that, depending on the conditions of soil formation, the development of erosion processes, and the properties of soil types and subtypes, the total biological activity of mountain and foothill soils decreases from very high

(81-100%) to high (61-80%), medium (41-60%), and low (21-40%) activity; in dark sierozem soils formed on Tertiary deposits the biological activity is very low (<20%) (Table 3).

Table 3

Biological activity of mountain and foothill soils, in % to max

Humus	Microbiological activity	Enzymatic activity	Soil respiration	IIEBSS
Mountain brown typical soils				
100	89	100	100	100
Mountain brown carbonate soils				
57	67	60	68	65
Dark seirozem earth formed on loess				
34	17	38	57	37
Dark serozem formed on Tertiary Neogene deposits				
14	7	17	43	21

According to the value of IIEBSS, the total biological activity of irrigated soils of the sierozem belt is different; it depends on the economic use and the duration of irrigation - it was found that old-irrigated meadow soils have high activity (61-80%), moor-meadow soils have moderate activity (41-60%), and other soil types and subtypes have a low level of general biological activity (Table 4).

Irrigated soils of desert zones, due to salinity to varying degrees, have very low (<20%) and low (21-40%) total biological activity according to the IIEBSS value, which is associated with poorer development of microorganisms, low enzyme activity, and respiration rate than in soils of foothill and mountainous zones, and irrigated soils of the serozem belt. The exception is the old-irrigated meadow soils of the desert zone, which are characterized by medium biological activity (Table 5).

Table 4

Biological activity of irrigated soils of the serozem belt, in % to max

Humus	Microbiological activity	Enzymatic activity	Soil respiration	IIEBSS
Old-irrigated moor-meadow soils				
36	50	50	57	50
Old-irrigated meadow soils				
47	60	57	72	61
Old-irrigated sierozem-meadow soils				
38	26	39	54	40
Newly irrigated light seirozem soil				
24	17	30	47	30
Old irrigated light seirozem soil				
24	28	23	44	31
Irrigated sierozem-meadow soils				
24	24	23	33	27

Therefore, the value of IIEBSS will make it possible to determine the total biological activity for each type and subtype of soils, compare the spectrum of soil zones, conduct a geographical analysis, and characterize the degree of influence of degradation processes on soil fertility, as well as to conduct the intercomparison of the levels of general biological activity of soils under consideration.

According to the scale proposed by E.I. Gaponyuk and S.V. Malakhov [3], the studied soils have very low (0-5 mg/10g/24 hours), low (5-10 mg/10g/24 hours) and medium (10-15 mg/10g/24 hours) CO_2 emission intensity (Fig. 6).

The value of IIEBSS in the studied soils varies greatly from very high to very low values. It was revealed that the main part of the mapped territory, that is, 84.0% of the area, is occupied by soils with low biological activity, 8.4% of the soil area - by very low, and 5.3% - by medium activity; only 2.1% of the area is characterized by high and 0 .1% by very high biological activity.

Table 5

Biological activity of irrigated soils of the desert zone, in % to max

Humus	Microbiological activity	Enzymatic activity	Soil respiration	IIEBSS
Irrigated takyr-meadow soils				
27	28	27	41	32
Old-irrigated meadow soils				
30	65	42	54	49
Newly irrigated seirozem -brown soils				
12	10	20	25	17
Newly irrigated meadow soils				
22	17	21	34	24
Newly irrigated takyr-meadow soils				
25	24	30	38	30
Newly irrigated moor-meadow soils				
14	15	19	25	19
Old-irrigated meadow-takyr soils				
25	26	25	34	28
Newly developed desert-sandy meadow soils				
18	14	17	27	20
Newly developed takyr-meadow soils				
22	21	21	29	24
Irrigated meadow desert-sandy soils				
17	10	16	18	16
Old-irrigated takyr-meadow soils				
13	10	20	15	15

A decrease in the level of biological activity of soils in the upper horizon of the studied soils to a low and very low level is an indicator of a violation of the restoring function of the natural resource potential of soils. According to some researchers, the loss of the boundary of sustainability and stability to the environment by more than 30% of their bioenergy potential should not be allowed [9].

Thus, the data obtained showed that it is appropriate to use integral index of the biological state of soils as a multi-component system for assessing the level of natural and anthropogenic impact on soil conditions; soils with a high level of biological activity are characterized by an increased ability to withstand negative impacts, and soils with low biological activity are characterized by weak stability.

REFERENCES

1. Amorim M.J.B. Soil ecotoxicology- from retrospective standard methods to prospective innovative tools - challenges for effect assessment and integration. Biodiagnostika v ekologicheskoy otsenke pochv i sopredelnix sred. //Mejdunarodnaya konferensiya. Moskva, 2013. - p.8
2. Gafurova L. A., Kadirova D. A., Djalilova G.T., Ergasheva O.Kh. Degraded soils of Surkhan-Sherabad valley and their biological activity. Journal of Critical Reviews Vol 7, Issue 2, 2020 -p.292-295
3. Gaponyuk E.I., Malaxov S.V. Kompleksnaya sistema pokazateley ekologicheskogo monitoringa pochv // Tr. Vsesoyuz. совещ. Obninsk, 1983. L.: Gidrometeoizdat. 1985. - S. 3-10.
4. Gafurova L. A., Ergasheva O.Kh. Bioindication in ecological assessment of eroded soils in mountain areas Journal of Critical Reviews Vol 7, Issue 2, 2020 -p.288-291
5. Zvyaginsev D.G. Metodi pochvennoy mikrobiologii i bioximii. M.: MGU. 1991. - 224 s.
6. Zvyaginsev D.G. Biologicheskaya aktivnost pochv i shkali dlya otsenki nekotorix yeyo pokazateley // Pochvovedeniye. 1978. - №6. - S. 48-54.
7. Kazeyev K.Sh., Kolesnikov S.I., Valkov V.F. Biologicheskaya diagnostika i indikatsiya pochv: metodologiya i metodi issledovaniy. Rostov-na-Donu.: Izd-vo Rostovskogo un-ta. 2003. - 204 s.
8. Xaziyev F.X. Metodi pochvennoy enzimologii. M.: Nauka. 2005.- 252 s.
9. Shoba S.A., Yakovlev A.S., Ribalskiy N.G. Ekologicheskoye normirovaniye i upravleniye kachestvom pochv i zemel / M.: NIA-Priroda. 2013. - 310 s.
10. M. Saidova, L. Gafurova, D. Kodirova, N. Shadiyeva, O.X.Ergasheva. Biodiagnostic survey of saline soils in the desert zone of Uzbekistan. ICECAE-2022 IOP Conf. Series: Earth and Environmental Science. 1142 (2023) 012073 IOP Publishing https://doi:10.1088/1755-1315/1142/1/012073