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Degradation Indices of Soil Salinity in the Territory under Study

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Abstract: When studying the agrochemical, agrophysical, and physicochemical properties of soils and the sum of integral indices of their ecological and biological state, degradation indices were developed by determining the ecological and genetic properties, and the level of influence of natural environmental factors on soils.

Keywords: Soil, microorganism, enzyme, gypsum, biological activity, integral index, ecological-biological condition, indicator.

1. INTRODUCTION

In the study of soil fertility, biological factors have recently attracted increasing attention, especially the microbiological activity of soils. Microbiological and biochemical characteristics of soil are the most complex sections of soil biodiagnostics. Microorganisms are very sensitive indicators that react sharply to various changes in the environment. This characteristic of micro-biocenosis communities is often found in the scientific literature [6]. It has now been proven that the same types of microorganisms can conduct opposite physiological processes under different conditions, for example, nitrogen fixation and denitrification, oxidation, and reduction [2].

One of the significant environmental factors that have a negative impact on the activity of microorganisms is salinity. When salinization occurs, a large amount of salts accumulates in soil, up to 6-7% in conditions of severe salinity. A large accumulation of salts in soil causes the death of soil microorganisms and leads to significant damage to soil fertility. At the same time, it should be noted that soil microorganisms react differently to different types of soil salinity [1,8].

Agronomically important groups of microorganisms that participate in the nitrogen and carbon cycles play an important role in soil fertility. Based on the number of these organisms, it is possible to indicate the state of soil and characterize the directions of the processes occurring in it. In this regard, it seemed necessary to conduct a quantitative account of the main physiological groups of microorganisms involved in the conversions of nitrogen- and carbon-containing substances [3,7].

2. Research Object and Methods

Soils of the studied territory of Uzbekistan (using the example of hydromorphic soils). Quantitative recording of individual physiological groups of microorganisms was conducted using the generally accepted dilution method, followed by sowing on solid elective nutrient media. The accounting and study of the functional diversity of microbial communities in soils was traditionally assessed at the level of physiological groups on appropriate media: ammonifying bacteria on meat-peptone agar (MPA), spore bacteria on MPA with the addition of wort (1:1), oligonitrophils and nitrogen fixers on Ashby medium, actinomycetes on a starch-ammonia medium, microscopic fungi on Czapek’s medium. The number of bacteria was expressed in colony-forming units per 1 g of soil (CFU/g).

The cost calculation of soils was performed using special formulas according to the manual “Biological Diagnostics and Indication of Soils: Methodology and Research Methods” by K.Sh. Kazeev et al.

The rate of "soil respiration" was determined by Koleshko's method modified by the Shtatnov method. Field work - including agrotechnical and agrochemical measures, phenological observations and field experiments was conducted in experimental plots planted with cotton under irrigation conditions. Collection of soil samples, to determine the quality of seed and technological properties of fiber, field experiments with fertilizers were discussed in "Statistical processing of data of field experiments", B.A. Dospekhov, Moscow, 1965. Fieldwork

was conducted using research methods such as "Methods of field experiments", B.A. Dospekhov, Moscow, 1979.
Calculation of the value of integral indicator of the ecological and biological state of soils (IIEBSS) was conducted on the basis of special formulas according to the manual "Biological diagnosis and indication of soil: research methodology and methods" by K.Sh. Kazeev et al. For this, the high value of each indicator was taken as 100, and other indicators were calculated as a percentage of this indicator.

$$B1= (Bx/ Bmax)x100\ \%\ (1),$$

here, B1 - the relative value of the indicator; B_x - the actual value of the indicator; B_{max} - the highest value of the indicator.
Then several relative indicators (the amount of humus, the amount of groups of microorganisms in soil, the activity of enzymes, and the rate of soil respiration) were summarized and their average value was calculated.

$$B_{ave}= (B1+ B2+ B3…+ Bn) / N\ (2),$$

here, B_{ave}– the average relative value of indicators; N- the number of indicators.
The integral indicator of the ecological and biological state of soil was calculated using the following formula:
IIEBSS = (B_{ave}./ B_{ave}. max) x 100 % (3), here, B_{ave}.– average relative of all indicators;
$B_{ave.\ max}$– highest relative of all indicators.

3. Results

Ammonifiers. It is known that bacteria are the most widespread form of microorganisms in soils. The number of bacteria in soils depends primarily on the soil type and its cultural condition. It also changes with depth and experiences seasonal fluctuations. The surface layers of soil (up to 30 cm) are especially densely populated; bacteria are also found in the subsoil [4,5].
Based on the results obtained, it could be noted that the largest number of ammonifying bacteria growing on MPA was found in typical gray soil; they amounted to millions (from 340 thousand to 930 thousand) per 1 g. Meadow soils were second in terms of the content of this group of microorganisms; here, their maximum amount reached up to 870 thousand/1g, and the minimum amount was 300 thousand/1g. Serozem-meadow highly saline soils are poor in this regard (201 - 644 thousand/1g).
The nature of the distribution of bacteria along the vertical profile of the studied soils also has a certain pattern. Observations of the number of bacteria growing on MPA show that the upper horizons are the richest in bacteria. The number of bacteria decreases with depth. This is mainly due to a decrease in the content of organic matter, as well as a change in the air regime of soils. In accordance with the distribution pattern of humus along the soil profile, changes in the content of bacteria occur. Another factor that affects the depth distribution of bacteria in soils is the root systems of plants.
Thus, microbiological studies have shown that in the studied soils the amount of ammonifiers, regardless of the soil type, decreases gradually from the upper horizons to the underlying horizons.
Oligonitrophils. Oligonitrophilic microorganisms are the most widespread organisms in the studied soils after ammonificators. The ability of oligonitrophils to develop at very low nitrogen levels in the substrate makes it possible for them to develop in conditions that are unfavorable for other microorganisms.
The number of oligonitrophils in a typical gray soil ranges from 110 to 480 thousand/1 g; as seen with other microorganisms, their amount is smaller in meadow soils (from 100 to 320 thousand/1 g). They are followed by gray-meadow soils; here their amount is from 51 to 260 thousand/1g, due to the salinity and gypsum content of soils.
There is a natural decrease in the number of studied microorganisms with depth, their number is higher in the upper, arable horizon (0-15 cm) and then, in the lower horizons of the soil profile (15-30, 30-50 cm), a decrease in the number of bacteria is observed. It should be noted that in these soils the decrease in the values of microorganisms is more pronounced than in similar soils in the region, which is related to an increase in the solid residue and gypsum values in soils.
The number of oligonitrophils in the arable layer of gray-meadow soil reaches up to 260 thousand/1g of soil, and in the subarable layer - 210 thousand/g of soil, and then decreases with depth to 83 thousand/1g; it is clear from the data, that the difference in the number of oligonitrophils between the horizons is small.
Actinomycetes. Actinomycetes have a wide distribution area and constitute an important part of microbiota. Sometimes these microorganisms are called radiant fungi or mold bacteria. High adaptability to various living

conditions allows them to take part in the transformations of a very wide group of substances. Analysis of the results on the content of actinomycetes and micromycetes in the studied soils showed that their numbers are significantly lower compared to microorganisms growing on MPA. The number of actinomycetes in typical gray soil ranges from 52 to 153 thousand/1 g. Meadow soils were second in terms of the content of this group of microorganisms; their maximum amount reached 88 thousand/1g, and the minimum amount was 37 thousand/1g. In this regard, gray-meadow medium- and highly saline soils have the smallest amount (28-76, 22-63 thousand/1g, respectively) [7].

Results have shown that in the studied soils the content of actinomycetes, like with bacteria, decreases from the upper horizons to the underlying horizons.

Micromycetes. Soil fungi play a significant role not only in biological processes occurring in the soil but also in plant life. The importance of fungi flora in nature and human economic activity is enormous. Soil fungi produce many medicinal substances - antibiotics, enzymes, they are the cause of a number of diseases of animals and agricultural plants. Research on soil fungi, in addition to scientific and educational interest, is also of great practical importance.

The number of micromycetes in typical gray soil ranges from 26 to 75 thousand/1 g, slightly less in meadow soils, from 22 to 68 thousand/1 g. They are followed by sierozem-meadow soils, where their number reaches from 20 to 56 thousand/1g.

The results of our research show that the content of micromycetes in soils depends on the degree of salinity and the depth of the soil horizon. The largest number of micromycetes was observed in non-saline typical gray soil, which is apparently due to the high content of humus and nutrients (Diagram 1).

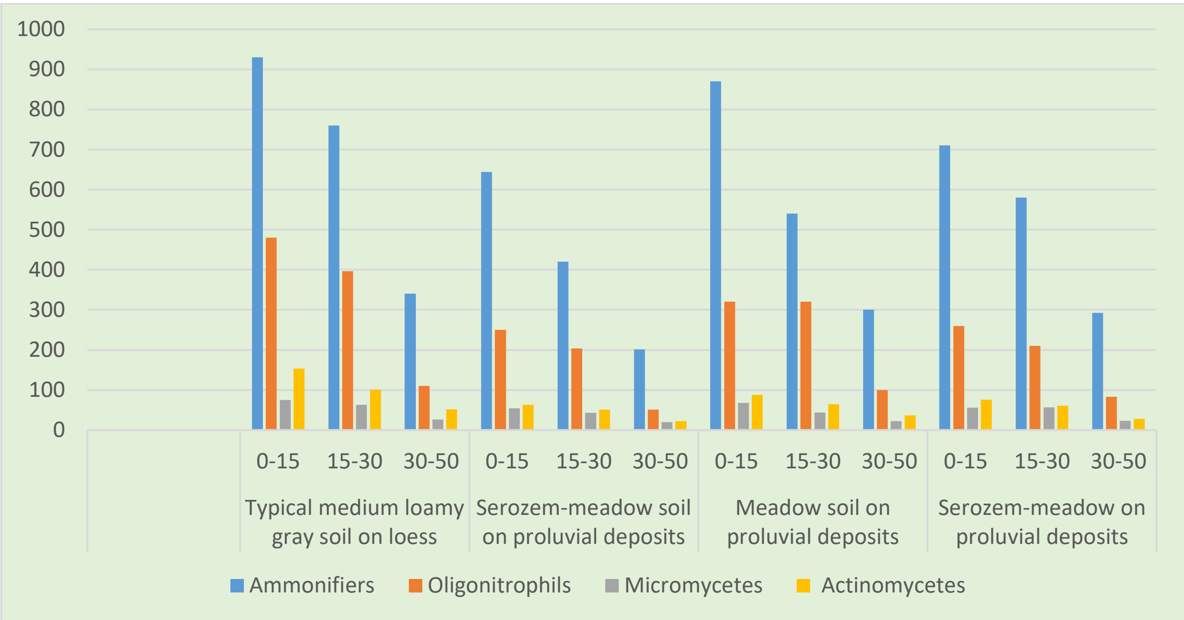


Diagram 1. Number of microorganisms in the soils
(thousand cfu/1 g of soil)

Nitrifiers. Microbiological oxidation of ammonia to nitrites and then to nitrates occurs during the process of nitrification, and is conducted by bacteria - nitrifiers. Our studies showed that nitrifying bacteria are poorly distributed in the soils under study. The low content of nitrifiers can be related to insufficient moisture content, high temperature, soil salinity, and a small amount of plant residues. The results of our studies showed that this physiological group of studied microorganisms is found in greater numbers in non-saline typical sierozem (20-28 thousand/1g), the somewhat lower amount is found in moderately and highly saline meadow soil (22 thousand/1g) and highly saline serozem-meadow soil (20 thousand/1g.). In addition, the content of nitrifiers in all types of soils decreases with depth.

Denitrifiers. Nitrates formed during the nitrification process due to their high solubility can be partially washed into the lower layers of soil and serve as a source of nitrogen for higher plants and some microorganisms; they can also be recovered as a result of the microbiological process of denitrification. Our research has shown that the number of denitrifiers in the studied soils amounts to hundreds of thousands in the upper horizons and tens of thousands in the lower horizons, for example, in typical gray soil, they amount from 28 thousand/1g to 250 thousand/1g, in meadow soil - from 14 to 200 thousand/1g, and in gray-meadow soil - from 15-160 thousand/1g. It should be noted that the number of bacteria of this group in the studied horizons changed very sharply with depth; its indicators depended on the values of the solid residue, where a positive correlation was observed.

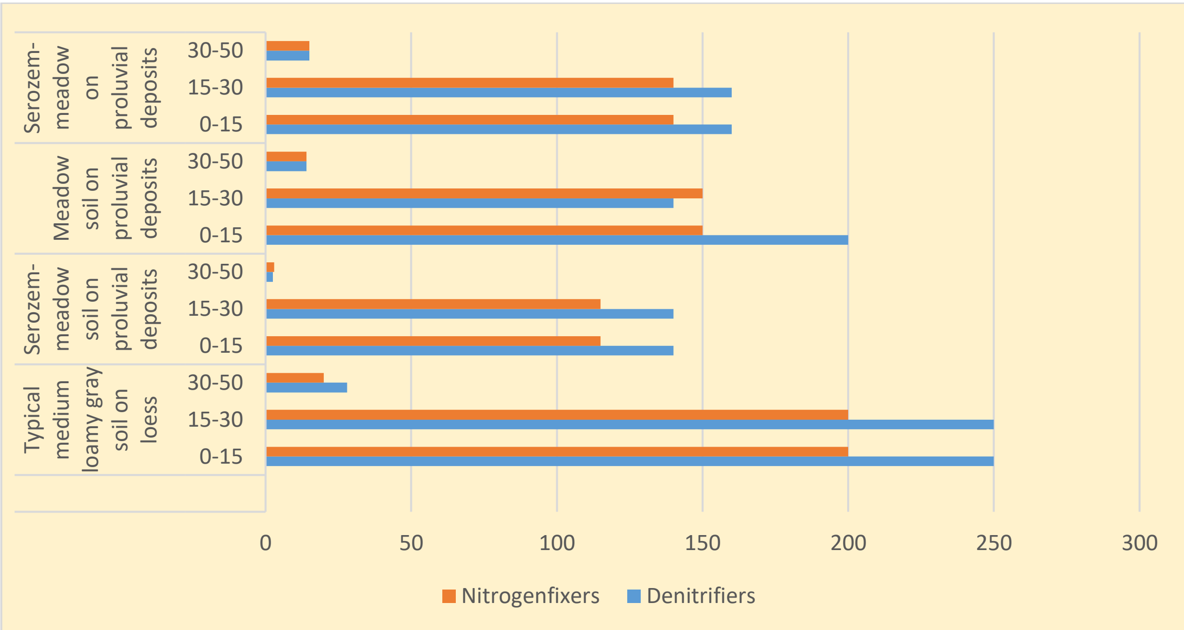
Nitrogenfixing bacteria. The reserves of nitrogen gas in the atmosphere are practically inexhaustible. Neither plants nor animals can take advantage of these huge reserves. Only prokaryotes, nitrogen fixers, have this ability.

Our research has established that the richest in this regard are non-saline typical sierozems (200 thousand/1 g), slightly inferior to them are medium and highly saline meadow soils (150 thousand/1 g) and highly saline sierozem-meadow soils (115-140 thousand /1g.). In terms of the content of free-living nitrogen-fixing bacteria, the lower horizons of the studied soils (30-50 cm) differed significantly from the upper (0-15, 15-30 cm) horizons; they were tens of times less in the lower horizons.

Butyric acid bacteria. Organic carbon-containing substances transform with the formation of intermediate compounds or CO_2 and H_2O. Depending on the path of decomposition of organic matter, a distinction was made between fermentation occurring under anaerobic conditions and oxidation occurring under aerobic conditions. The results of identifying the number of butyric acid bacteria in the studied soils showed that the number of this physiological group of microorganisms is higher in non-saline typical gray soil (25 thousand/1 g), and is slightly inferior to them in moderately and highly saline meadow soils (20 thousand/1 g), less of them are found in highly saline gray-meadow soils (11 thousand/1 g).

A comparison of the results obtained across soil horizons indicates the active development of butyric acid bacteria in the upper horizons. This is due to the high content of organic matter.

Decomposition of cellulose. Under natural conditions, huge amounts of cellulose end up in soil, where they undergo biological transformation with the participation of soil microorganisms-cellulose-degrading bacteria. Studies of the number of aerobic cellulose-degrading bacteria in soil samples have shown that their highest content is characteristic of typical gray soils, where their number is 15-35 thousand/1g, in meadow soils - (11-25 thousand/1g), followed by slightly lower amount found in gray-meadow soils (11-15-20 thousand/1g) (Diagram 2).



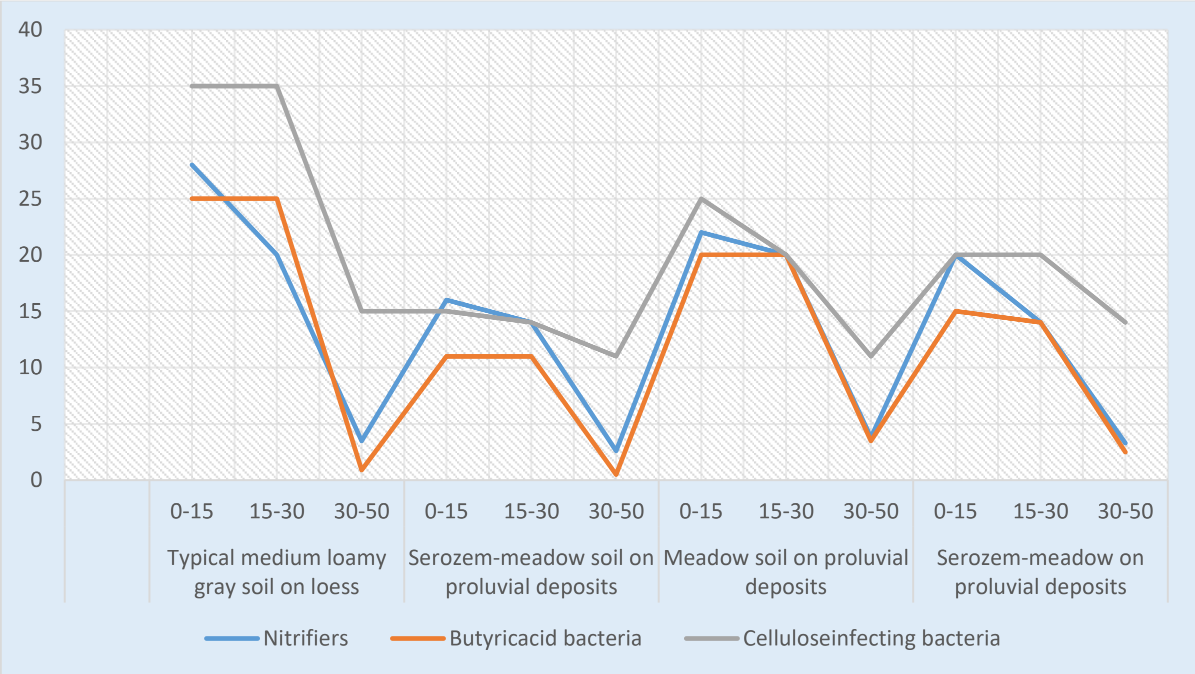


Diagram 2. The number of microorganisms in the soils
(thousand cfu/1 g of soil)

As the results show, in the studied soils, microorganisms involved in the decomposition of cellulose develop depending on the types of soil, hydrothermal conditions, composition of organic substances, and others. It should be noted that with the depth of the soil horizon, the number of aerobic cellulose-degrading bacteria decreases. From the above data, it was revealed that the studied soils are to some extent susceptible to salinization, and from the results presented, it is clear that salinization to some extent affects the microbiological activity of soils.

The studied territory falls within the semi-desert gray-earth zone with its characteristic geomorphology, climate, and vegetation cover. The ruggedness of the relief, the lithological features of the underlying rocks, the complexity of hydrogeological conditions, and other natural factors determined the formation (in addition to the zonal type of sierozems) of meadow-sierozem, sierozem-meadow, meadow and swamp-meadow soils and solonchaks, which differ significantly in salinity, gypsum content, carbonates, and other reclamation indicators.

As noted by a number of researchers [6, 8, 9, 11, 16, 37, 42, 44], in arid soil formation, informative indicators are the coefficient of mineralization of organic matter (K_{mom}), the coefficient of transformation of organic matter (K_{tom}) and the integral indicator of the ecological and biological state of soils (IIEBSS).

Research shows the dependence of these indicators on the degree of salinity and gypsum content. Thus, for soils, when considering their salinity, indicator (K_{tom}) is 1.77-0.59 (typical gray soil, non-saline, medium loamy soils), 0.68-0.77 (gray soil-meadow, highly saline, light loamy sandy soils), 0. 96-0.41 (meadow medium and highly saline, light loamy sandy loamy soils), 0.84-0.30 (grey earth-meadow, medium and highly saline, sandy loamy soils).

According to the coefficient of transformation of soil organic matter, soils can be arranged in the following order: (from non-saline to highly saline soils), indicator (K_{mom}) is 0.164-0.152 (typical sierozem, non-saline, medium loamy soil), 0.097-0.109 (serozem- meadow, highly saline, light loamy sandy soils), 0.101-0.123 (meadow medium and highly saline, light loamy sandy loamy soils), 0.107-0.095 (grey earth-meadow, medium and highly saline, sandy loamy soils) (Table 1).

Table 1. Transformation coefficient of organic matter (considering salinization processes) in the soils

Soils	**K_{mom} (SAA/MPA)**	**K_{tom} ((MPA+SAA) x (SAA/MPA))**
Typical gray soil, non-saline, medium loamy	0.164-0.152	1.77-0.59
Serozem-meadow, highly saline, light loamy sandy	0.097-0.109	0.68-0.77
Meadow medium to highly saline, light loamy sandy loam	0.101-0.123	0.96-0.41

Gray-meadow, medium and highly saline, sandy loam	0.107-0.095	0.84-0.30

Based on the results obtained, degradation indicators are recommended for saline gypsum soils in the semi-desert zone. These criteria make it possible to assess, map, and conduct soil-ecological and soil-reclamation monitoring, being an indicator that determines the degree of degradation of saline soils in the region (Table 2).

Table 2. Degradation indices of gypsum soils

Indicators	Soil not affected to degradation	Weakly degraduated soils	Moderately degraded soils	Strongly degraded soils	Very strongly degraded soils
Humus, %	>1.8	2.3	1.6	1.5	0.97
Dry residue, %	<0.6	0.6-0.9	1.0-1.8	2.0-3.0	>3
Amount of gypsum, % $CaSO_4*2H_2O$	>2	2-9	10-19	20-29	30-41
Toxic salts, according to soil profile, %	>1.33	1.182	1.936	1.592	3.661
Mineralized groundwater content, g/l	2.4	8.4	12.6	16.4	25.1
Degree of salinity	Non-saline	Weakly saline	Moderately saline	Strongly saline	Solonchaks
Relative BA	100	82	62	60	15
K_{tom}	1.77-0.59	0.68-0.77	0.96-0.41	0.84-0.30	0.49-0.17
K_{mom}	0.164-0.152	0.097-0.109	0.101-0.123	0.107-0.095	0.112-0.075
IIEBSS %	100	87	71	42	29

4. Conclusion

Thus, microbiological analysis showed that the soils under study are to some extent susceptible to salinization and affect the microbiological activity of soils. For example, in non-saline typical sierozem, the activity of microorganisms is higher than in moderately and highly saline meadow and sierozem-meadow soils. These soils are poor in humus and nutrients and, accordingly, have low biological activity. The largest number of microorganisms are found in the turf horizon in all studied soils; in the lower part of the profile, their number sharply decreases.

Among the studied groups of microorganisms, there is a predominance of ammonifiers, the second in number is actinomycetes, and the next places are occupied by nitrogen-containing and denitrifying bacteria, and cellulose-degrading microorganisms and fungi. A low content of butyric acid and nitrifying bacteria was noted.

Changes in the number of microorganisms by season, soil subtype, and depth of the soil horizon can be explained by a lack of water and weak accumulation of organic matter along the soil profile.

The study of agrochemical, agrophysical, physicochemical properties and the sum of integral indicators of the ecological and biological state of soils makes it possible to determine the level of impact of their ecological and genetic properties and natural environmental factors on soil fertility and land degradation.

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