MODIFYING THE PROPERTIES OF THE ZONAL SOILS USED IN AGRICULTURE OF MOLDOVA: MONITORING AND MANAGEMENT

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Abstract

The physical, chemical and biological properties of zonal soils located in different zones of the Republic of Moldova have been investigated with a view to control and improve the quality. Long arable soils with the normal profile (typical chernozem, leached chernozem and gray forest soil) were compared to the virgin soil and soil which was under long term fallow. The soils used long term in the agriculture process was characterized by unfavorable properties for crop growth. Degradation led to modifying the all physical, chemical and biological indexes in negative direction. The soils of natural ecosystems are characterized by favorable physical and chemical properties and are ideal standards in regard to the composition, biomass and activity of the biota. The long use of soils in agricultural production led to the imbalance between the processes of decomposition and humus formation and promoted the decrease of soil biota stability and degradation. The values of most soil indices decrease in the following sequence: virgin and fallow land → arable unfertilized land. Soil monitoring and management with the involvement of areas with natural vegetation in a crop rotation system created conditions for the improvement the soil fertility and biota's vital activity in the soil which degraded as a result of a long-term arable use.

Key words: agricultural management, chernozem, monitoring, soil properties, soil biota

The extensive chaotic existing system of Moldovan agriculture leads both to lower agricultural output and the degradation of soil resources. The situation may be changed through gradual implementation while enhancing land, sustainable agricultural system in which agriculture and research are concerned not only high yields but also to optimize the system as a whole to maintain long-term soil productivity. To monitor changes in soil properties used in the agriculture was carried out the pedologycal investigations in order to create the initial database of quality status of the main types and subtypes of zonal soils. On the arable and virgin land were placed 40 key-polygons, in which were considered the main values of soil properties. For some subtypes of zonal soils were placed polygons key on the fallow lands, which made the possibility to determine the level of degradation of arable soil characteristics under the influence of anthropic factors and the speed of restoration of these properties under the influence of natural vegetation. On the basis of polygons monitoring located on the main variants of long field experiences were developed agro-technical and improvement measures of soil quality status. The data obtained allowed to develop the forecasts and recommendations for sustainable land management and mitigate the consequences of ecopedological unfavorable factors.

MATERIAL AND METHOD

Experimental sites and soils. Two experimental sites located in different zones of the Republic of Moldova have been tested. Various ways of treatment-utilization of the soil and land management practices in the condition of long-term field experiments have been analyzed.

The first site was in the north, on the long-term field experiments of the Research Institute of Field Crops "Selectia" (Beltsy). It had plots with fallow land (60-30-15 year-old) and the long-term arable land with crop rotation (management without fertilizers). The soil was the typical chernozem. *The second site* was located in the center of the country, in the Ivancea village, Orhei district. The natural land under fallow (40-60-year-old), forests and the long-term arable land were tested. Soils were presented by the leached chernozem and the gray forest soil.

Physical and chemical properties. In the field was performed morphological description, soil sampling from genetic horizons (in the center of each horizon), determination of apparent density in all profiles and semi profiles for Ahp1, Ahp2, Ah horizons (up to 50 cm depth). In the side profiles of

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the polygons investigations have been carried out to the depth of 100-120 cm. In laboratory soil samples were performed using classical analysis of existing methods. In the bureau work phase the results were systematized, statistically processed and presented in tables, diagrams, maps. Research on the key polygons will be repeated at intervals of 5-10 years.

For each polygon was developed the monitoring passport that includes information about the coordinates of the polygon, land use and soil characteristics at the time of research. Data on key characteristics of soils polygons being systematized, generalized and statistically processed forms an initial information system (start of monitoring observations) regarding the recent state of soil quality in the Republic of Moldova (Cerbari, 2010).

Biological properties. The state of invertebrates was identified from test cuts by manually sampling the soil layers to the depth of soil fauna occurrence applying Gilyarov and Striganova's method (Gilyarov and Striganova, 1987). The microbial biomass was measured by the rehydratation method based on the difference between C extracted with 0.5 M K_2SO_4 from dried soil at 65-70^{0}C within 24 h and fresh soil samples with K_c coefficient of 0.25 (Blagodatsky, et al., 1987). The K_2SO_4 – extractable organic C concentrations in the dried and fresh soil samples were simultaneously measured by dichromate oxidation. The quantity of K_2SO_4 – extractable C was determined at 590 nm using a spectrophotometer. Counts of humus-mineralizing microorganisms were obtained on agar plates (Zvyagintsev, D.G., 1991). Sampling was carried out from the 0-30 cm layer.

RESULTS AND DISCUSSIONS

The comparative characteristics of arable and fallow typical chernozems. Average statistical parameters of soil research monitoring polygons placed in aim to investigation of the features of typical chernozems are characteristic for their spread areas, and can be used to detect changes in the quality status of typical arable chernozems. Parallel research of the arable and fallow (15, 30, 60 years) typical chernozems made it possible to determine the degradation of arable soil characteristics and assess the speed of restoration of these properties under the influence of natural vegetation in component that dominate grasses. It was established that whole profile of typical chernozems being fallow during 60 years under the influence of natural vegetation have fully restored main initial parameters (grainy structure and humus content), characteristics for virgin soil and can be considered as standards *(fig.1 a, b).*

Recent plowed layer of typical arable chernozem is characterized by lump structure and massive structural elements fully compacted; under the recent arable 0-25 cm layer stands out a very compact layer (25-35 cm) with prismatic, lumps or monolithic structure. The content of agronomically valuable aggregates in the recent arable layers (0-25 cm) and post arable (25-35 cm) of typical chernozems is small or medium (30-50%), these layers have lost their resistance to compaction.

Typical chernozems virgin and fallow 15, 30 and 60 years have a great grainy structure and low compaction of the layer 0-30 cm. As a result of fallow the typical chernozems have restored the original quality of structure characteristic for virgin soils and partially the content of humus. Typical chernozems fallowed 30 and 15 years have favorable achieved the initial condition of the structure, only in the 0-30 cm layer. The lower part (30-50 cm) of layer is characterized till now by preponderantly prismatic structure, the apparent density reaches 1.40 to 1.41 g/cm^3. Therefore, the grassy steppe vegetation with its fasciculate root system characteristics restores damaged structure


a


b

Figure 1 a. **Typical chernozem arable, plowing at 25-28 cm; b. Typical chernozem followed 60 years**

of soils mainly in the active layer 0-30 cm. Restoring the physical quality of the soil unclogged layer by the fallow is more complicated, but this process can be fully achieved only by unclog and repeated follow these soils after 15-20 years primary fallow. In result of intensive process of soil dehumification the average content of humus in the 0-25 cm layer of typical chernozem arable in comparison with fallow 60 years decreased by 2.20% or 35%, the values of hydrolytic acidity by 1-2 me. The results confirm that nowadays in result of dehumification the typical chernozems have lost about 33-35% of original content of humus. Restoration speed of the humus content in the 0-30 cm layer of typical chernozem follow 15 years under the action of perennial grasses without discharge their air mass is about 0.06% annually for the layer 0-30 cm and 0.04% annually for the 0-50 cm layer *(tab.1).*

Keeping existing farming system of typical chernozems will lead to intensification of humus losses and compaction of the arable layer with serious consequences for the state of soil quality and agricultural production (Leah, 2013).

Table 1

Weighted average data on typical chernozem properties

Horizons and depth, cm	Fraction <0,01mm	Fraction <0,001mm	HC*	CD*	D*	AD*	TP*	Humus, %	pH	HA*
Typical chernozem fallow										
Aţ1 0-10	63,8	35,5	8,1	-11	2,60	1,13	56,5	6,70	6,8	1,8
Aţ2 10-25	63,9	36,5	7,5	1,4	2,61	1,30	50,2	5,94	6,9	1,8
A 25-50	63,3	36,6	7,8	5	2,63	1,31	48,3	4,23	7,1	0,4
Layer 0-25	63,8	36,0	7,7	-2	2,60	1,23	51,8	6,24	6,8	1,8
Layer 0-50	63,6	36,3	7,7	2	2,62	1,28	50,0	5,23	6,9	1,1
Typical chernozem arable										
Ap1 0-10	62,8	38,4	6,9	-3	2,62	1,23	53,0	4,08	6,2	3,8
Ap1 10-25	63,5	37,6	6.9	5	2,62	1,35	48,5	3,98	6,2	3,6
Ap2 25-35	63,5	38,4	6,9	12	2,63	1,44	45,2	3,78	6,2	3,3
A 35-50	63,4	37,9	7,0	7	2,64	1,38	47,7	3,15	6,5	2,8
Layer 0-25	63,2	37,9	6,9	2	2,62	1,31	50,4	4,02	6,2	3,7
Layer 0-50	63,3	38,0	6,9	5,4	2,63	1,36	48,3	3,71	6,3	3,3

**HC –Hydroscopicity coefficient, %; CD – Compaction Degree; D – Density, g/cm^3; AD – Apparent balanced density, g/cm^3; TP – Total porosity, %; HA – Hydrolytically acidity, me/100g sol*

The comparative characteristics of arable and fallow cambic chernozems. Cambic chernozems (leachate) have polygenetic origin, were formed as a result of the combination of several pedogenesis phases: under forest vegetation; under historic anthropogenic influence - after deforestation; under the steppe vegetation for long periods used on the arable. Recently in the investigated leachate chernozem profiles the pedogenesis phase under forest vegetation are manifested by following morphological characters: the brown - reddish color of horizon BW2, prismatic structure and compaction of horizons BW1 and BW2, the presence in the lower part of soil profiles of holes ex rotted tree roots, low humus content in compared profile.

Thus, the leachate chernozems on the most areas of their spread were formed as a result of transformation of forest soils under the influence of natural steppe vegetation, their restoration for a long rest historical period. The investigated arable cambic chernozem differs from ones followed. Its are characterized by clay-loam texture low differentiated in the profile, middle quality of structural composition, moderate compaction of the arable layer, high compaction of the Bhw2 Bhw1 horizons.The cambic chernozem humus profile is decarbonated. The brown color of investigated soils is obtained due process "in situ" of mineral part of these soils. Humus content in arable chernozem cambic is comparatively small and varies in limits: 3.2-3.5% - in the arable layer; 2.2-2.5% - in the horizon Bhw; 1.0 - 2.0% - in the horizon Bhw2; 0.7-1.0% - in the horizon BCk1.

The values of C: N ratio – from 8.9 to 9.4, which confirms that the intensity of annual flows of fresh organic matter in the soil is low. In terms of humus content and value ratio C: N the cambic chernozem differ essentially from those followed, that are more high content of humus (3.5-4.0%) and the values of the ratio C: N is 10-12.

Investigated leachate chernozems are moderately supplied with mobile forms P_2O_5 and K_2O. Hydrolytically acidity of these soils is comparatively small - from 1.7 to 2.5 me, the content and composition of exchangeable cations in the soil adsorption complex investigated soils is typical for chernozems. The amount of cation exchange capacity ranges from 31 me in the horizon Ahp1 of investigated soils, up to 22 me in Ck horizon. In general, leachate chernozems used on the arable are characterized by satisfactory chemical and physical properties.

The main factors of degradation of cambic chernozems are dehumification, destructuration, secondary compaction of the arable layer, decreasing reserves of nutrients in the soil, regular and temporary excess of rainwater (in fine textured soils), high compaction of depth layer of 25-35 cm, that can be restored by the chiseling work of the 35-40 cm soil depth. Comparative characteristics of virgin and arable gray soil. Gray virgin soils is characterized by clear differentiation of the profile in the range of 0-30 cm depth, stands out three genetic horizons - Ahţ, AEh and BEhtw with medium texture and low compaction, in which is located the eluvial (eluvial - cambic) horizon high compacted *(fig.2 a, b).* In the arable layer (0-30 cm) of soil used in agriculture about 100 years, consisting of three genetic horizons of virgin soil, there were radical changes in color (reddish-brown became), texture (became middle-fine), structure, compaction, humus content (decreased by 1.50%), and hydrolytic acidity (decreased by 2-3 times).

a b

Figure 2 **a. Gray soil arable, plowing at 30 cm;**
b. Gray forest soil, with differentiated texture

Changes of the hydrothermal regime, capacity and character of bioaccumulation process in the arable land led to the modification of the direction and intensity of pedogenesis elementary processes in arable gray soils: has stopped the eluvial-alluvial process of clays; has intensified the deterioration *"in situ"* of mineral part. Soil tillage and destructuring of arable layer had resulted in loss of resistance to compaction: the apparent density balanced at the 10-30 cm depth (below the periodic worked layer) to mid-summer period reaches values equal to 1.50 to 1.55 g/cm³, the degree of compaction - equal to 17-18%, as a result, the state of the physical quality of this layer become unfavorable for the crop growth *(tab.2)*.

The existing system of agriculture cannot remedy the physical characteristics of gray soil arable and require radical changes in agricultural system. Combating compaction of the arable layer of the gray soil is possible only with long cultivation of perennial grasses with dominate up to 30 percent of the grasses – the plants with fasciculate root system that contribute to the formation of hydrostable grain structure. For more efficient exploitation and maintenance the soil in the more favorable condition it is necessary to adapt the agricultural system to the specific characteristics of the gray arable soil; to implement crop rotation with ameliorative remediation effect, mineral and organic balance fertilization, execution of the tillage in the optimal period; application of the subsoiling (plowing) once in every 2 -3 years.

Table 2

Characteristics of arable and virgin gray soil

Horizons and depth, cm	Fraction <0,01mm	Fraction <0,001mm	HC*	CD*	D*	AD*	TP*	Humus, %	pH	HA*
Gray soil virgin										
Ahţ 0-7	32,9	15,2	7,3	-50	2,56	0,72	71,9	8,57	5,9	6,0
Aeh 7-18	40,5	22,0	6,0	-17	2,60	1,10	57,7	2,90	5,5	10,5
BEhtw 18-30	43,0	26,1	6,3	5	2,62	1,38	47,3	2,14	5,8	8,8
Bhtw 30-50	50,9	35,3	7,4	17	2,67	1,52	43,1	1,46	5,9	5,7
Layer 0-30	39,7	22,1	6,4	-16	2,60	1,12	56,9	3,92	5,7	8,8
Layer 0-50	44,2	27,4	6,8	-3	2,63	1,28	51,4	2,94	5,8	7,5
Gray soil, used on the arable 100 years										
Ahp1 0-10	50,6	31,0	6,9	5	2,59	1,34	48,3	2,45	5,9	3,1
Ahp2 10-30	50,9	32,0	6,9	18	2,60	1,51	41,9	2,33	6,0	2,9
Bhtw 30-50	53,7	35,4	8,3	19	2,64	1,53	42,0	1,53	6,1	2,7
Layer 0-30	50,8	31,7	6,9	14	2,60	1,45	44,0	2,37	6,0	3,0
Layer 0-50	52,0	33,2	7,5	16	2,61	1,48	43,2	2,03	6,0	2,9

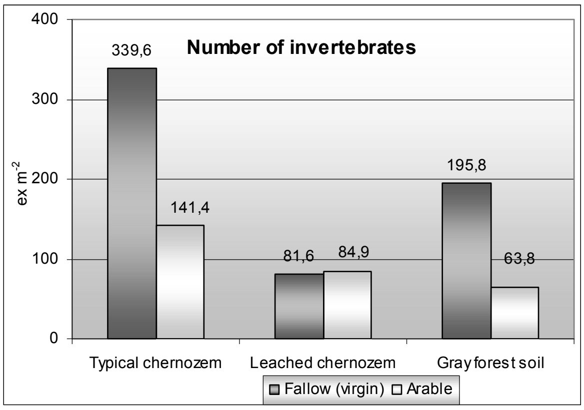
**HC –Hydroscopicity coefficient, %; CD – Compaction Degree; D – Density, g/cm^3; AD – Apparent balanced density, g/cm^3; TP – Total porosity, %; HA – Hydrolytically acidity, me/100g sol*

In conclusion it can be remarked that gray soils are characterized by favorable chemical and physical properties for crop growth. Arable soils, as a result of high anthropic impact have changed the characteristics mainly in the negative direction.

Biological properties. The soils of natural ecosystems are characterized by favorable physical and chemical properties and are ideal standards in regard to the composition, biomass and activity of biota. Biota of virgin and fallow soils exists in conditions of the high supply of the organic matter and the conservation of resources that have been formed within the limits of the ecosystem. Undisturbed virgin and fallow soils are medium for the reproduction of various species of invertebrates and microorganisms and have a high level of the biomass. A characteristic feature of natural soils is the high concentration of invertebrates (88.2 - 91.8%) and. *Lumbricidae* family (77.8 - 78.7%) in the upper layers of soils and in the litter. Saprophages prevail in the composition of the edaphic fauna in the soil standards. The concentration of microorganisms in the top layer reaches 1631.1 μ C g^{-1} of soil.

The number of invertebrates in natural soils is reached to 195.8-339.6 ex m^{-2}, *Lumbricidae* family – to 83.0-227.3 ex m^{-2}, and its biomass – to 46.9-82.2 and 41.5-61.2 g m^{-2} accordingly. The exception is the leached chernozem under fallow with the low faunal abundance. Perhaps this fact is connected with the low moisture content in the soil during the selection of faunal samples. The share of earthworms in the total abundance of invertebrates constitutes of 35.3-66.9 % and their biomass – 59.1-88.5 % in the soils of natural ecosystems. The weight of one exemplar of *Lumbricidae* family in chernozems constitutes 0.24-0.27 g, in the gray forest soil – 0.5 g. The largest share of invertebrates and *Lumbricidae* family is concentrated in the 0-10 cm layer of soil and in the debris layer. The soils of natural ecosystems are characterized by a high diversity of invertebrates. In addition to the *Lumbricidae* family species from the families of *Formicidae*, *Arthropoda, Carabidae, Araneaie, Apidae, Forficulidae, Pieridae, Pentatomidae, Coccinelidae* and other have been found in soils of natural ecosystems. The soil under the natural vegetation contains 5-12 families of invertebrates.

The current status of the biota of agricultural soils in the all zones of the Republic of Moldova is characterized by the significant reduction in the abundance, biomass and activity in comparison with soil's standards that are in conditions of natural ecosystems (*fig. 3 and 4*). The long use of soils in agricultural production led to the imbalance between the processes of decomposition and humus formation that promoted the decrease of soil biota's stability and its degradation. The decline of the natural resistance of soils is mainly determined by the reduction of their biochemical potential and the diminution of zones of homeostasis of invertebrates and microorganisms. The size of the homeostasis and the natural resistance of biota in arable soils decreases from the typical and leached chernozems to the gray forest soil. Indices of the number and biomass of invertebrates decreased in arable soils by 2.4-3.1 and 1.2-6.3 times respectively in comparison with virgin and fallow soils. Agricultural soils contain only 2-5 families of invertebrates. Microorganisms in virgin and fallow soils are concentrated in the 0-60 cm layer (78-83 %), the biomass index decreases sharply in the soil profile to a depth of 30-50 cm. The highest levels of the microbial biomass and organic carbon content have been determined in the a_1 horizons of soil profiles. Microorganisms in the virgin and fallow soils were found at the depth of 138 cm, and some species were encountered at the depth of 200 cm. the abundance of heterotrophic microorganisms in soils under the natural vegetation is provided by the high level of the organic matter content. The total biomass of microorganisms in natural soils constitutes in average 355.8-876.0 μ g C g^{-1} soil in the 0-30 cm layer. It is much greater than its abundance in arable soils (*fig. 2*). A similar trend has been noticed in the number of the heterotrophic bacteria and fungi (Senicovscaia, 2012). But the number of the humus-destroying microorganisms and actinomycetes in most cases is much lower than in the soils of agricultural ecosystems. The characteristic feature of microbial communities of agricultural soils is the high content of the humus-mineralizing microorganisms.



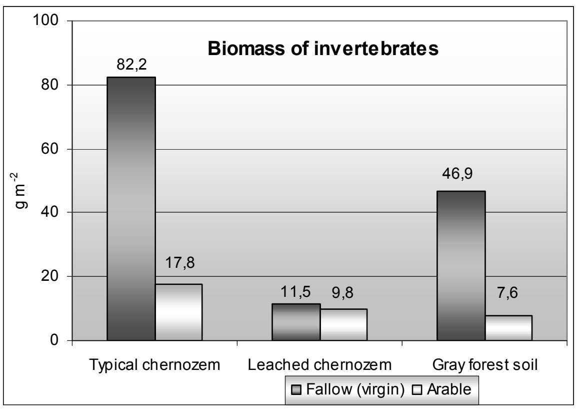
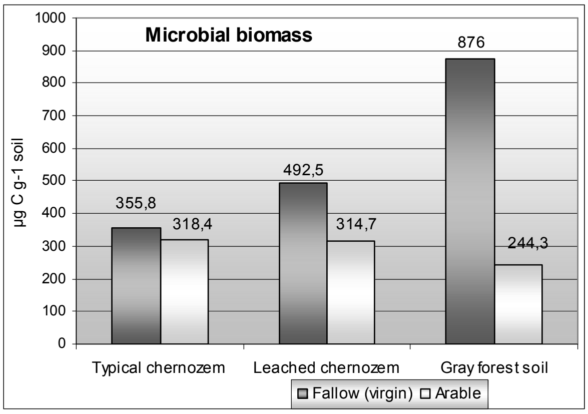


Figure 3 **Invertebrates in soils of the Republic of Moldova under different land management (mean values, n=3-32)**



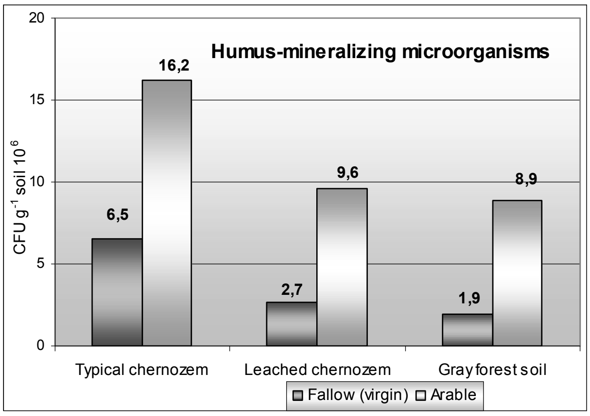


Figure 4 **Impact of the long-term arable utilization of soils on the microbial biomass and humus-mineralizing microorganisms (mean values, n=8-33, 0-30 cm layer)**

CONCLUSIONS

Agricultural overexploitation in the last 3-4 decades have resulted in ecological fatigue and decreased of soil quality status in Republic of Moldova. Intensive processes of degradation of soil cover were expanded about 56 percent of agricultural land, continues to increase erosion and landslide affected areas, the processes of humus losses, damage the structure and compaction, alkalization, salinity and marsh, intensified droughts. These processes lead to the disruption of biological cycles, balance of nutrients and humus in the soils, damage and decrease their fertility.

The long use of soils in agricultural production led to the imbalance between the processes of decomposition and humus formation and promoted the decrease of soil biota stability and degradation. The values of most soil biological indices decrease in the following sequence: virgin and fallow land → arable unfertilized land. A soil management with the involvement of areas with natural vegetation in a crop rotation system created conditions for the improvement of the biota's vital activity in the soil which degraded as a result of a long-term arable use.

Monitoring of soil quality is a complex system based on the ecopedological parameters and indices coverage spatial and temporal conditions, which provides the necessary information to develop strategy and tactics to prevent the consequences of atrophic activity and natural disasters, preparing forecasts and exercise operational control over efficiency measures against degradation processes.

In future the network of monitoring polygons in Moldova should be broadened and covered all the climatic zones and soils. It is also necessary to organize observations polygons of soils monitoring in the vineyards and orchards, which are subject to extremely high anthropogenic impact.

To introduce in the Moldova a system of soil quality monitoring would be necessary to place a network of about 135-150 key-polygons. Comparing the results obtained periodically give way to highlight changes in the state of soil quality as a result of anthropogenic pressure and natural disasters and to recommend appropriate measures to mitigate adverse consequences. Regular surveys of soil for the purpose of monitoring will allow detecting changes in quality condition and recommending necessary measures to maintain long-term soil fertility in the country.

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