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# ENSURING THE SUSTENABILITY OF ARABLE CHERNOZEMS THROUGH MANAGEMENT OF THE HUMUS FORMATION PROCESS

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***Abstract***

*The current stage of arable chernozems development is determined by the change of pedogenetic regimes as a result of agrogenic changes caused by long-term agricultural use, but also by changing the soil climate induced by climate change from the Carpatho-Danubian-Pontic space. Under such conditions it is considerably reduced the priority role of humus formation process which is responsible for the evolution of the biorutinar soil system. As a result, the chernozems in the region entered in a stagnant evolutionary phase being extremely vulnerable to various degraded processes. Certifying the chernozems sustainability can be ensured in complex technologies adaptive-landscape-improved.*

***Key words***: *arable chernozems, biorutinar systems, humus, soil system, chernozems sustainability*.

## INTRODUCTION

Through the concept, biosphere functions and ecosystems of the soil cover (Dobrovolski, 2000), the paradigm of sustainable development means ensuring enlarged reproduction of its productive function. Achieving this goal requires first, carbon sequestration and nitrogen in the humus-sphere and reducing the share of greenhouse gases, originating from functioning of the soil cover. In this context, we consider that chernozems have a special role in the Biosphere.

Although these soils account just 268 million hectares, they are most productive and have the greatest capacity to sequester carbon and nitrogen, and preserve for a long period of time (on the pedologic scale).

Another important issue inherent to carbon and nitrogen sequestration consists in ensuring the unidirectional reproduction trend of the clod-grainy chernozems structure, capable of providing stable functional regimes that would ensure chernozems sustainability conditions induced by climate change.

In this paper the biophysics framework is based on theoretic and practice presentation to ensure technologies of chernozems sustainability under climate change.

## MATERIALS AND METHODS

The conceptual framework of this research methodology which targets biologization process is ensured by the natural-anthropogenic chernozems pedogenesis from the Carpatho-Danubian-Pontic space, the concept of soil resources, the concept of bioenergetic soil resources and the concept of adaptive-landscape-improved technologies elaborated in the Scientific Research Laboratory Pedogenetic Processes of Moldova State University.

This study includes researches in the field and in the laboratory through standard methods application. At the same time, a series of research were carried out within the Republic Center of Applied Pedology during the years 2003-2015 under the leadership of one of the authors of the current study. In order to identify the evolutionary trend of soil humus status indices were systematized a series of studies from the Republic Center of Applied Soil Science.

## RESULTS AND DISCUSSIONS

On the basis of soil formation process, establishment and development of natural fertility stay the same biochemical processes of transformation of substances and energy, and the integration of biotic and abiotic constituents in the soil ecosystem biorutinar system.

The biochemical processes determine the circuits of carbon, nitrogen, phosphorus, sulfur and organogenic elements, but also the meaning and intensity of the pedogenetic process, controls soil evolution, fertility level, characterizes the degree of disturbance in agroecosystems under the action of natural and anthropic factors.

The current stage of natural-anthropogenic evolution of the pedogenesis process is characterized by unidirectional reduction of soil biogenesis, primarily due to reduced priority role in the process of humus formation in the soil development and their natural fertility.

The main causes of soil reduction, priority of humus formation process are:

- Perturbation, anthropogenic degradation of the pedofunctional framework (pedofunctional regimes) to achieve the process of humus formation;
- Low energy quality of humus sources, represented by organic residues;
- The deficit of the necessary biological nitrogen in order to achieve the process of humus formation;
- Accelerated intensity within decomposition process of the organic residues (in the absence of humiferous detritus) with the formation of "anthropic" humus less stable;
- Stressful state of soil biota following the "chaotic" dynamics through the composition amount and limits storage of organic waste;
- The considerable reduction of microbiotic biomass to soil from 28-30 to 1-2 t/ha as an active humus renewable source;
- Spatial incoherence of the deposition area of organic residues and the optimal conditions in the deployment of humus formation processes as a result of the intensive degradation of the arable layer;
- The decomposition and biodegradation as a result of increased humus;
- Humus losses due to water and wind erosion.

Reducing the priority role of humus formation process involves a number of quantitative changes in the evolution of the organic substance system through the stability reduction of the organic matter system as result of changing the ration between humiferous detritus and humus.

According to the researchers conducted within the biological station of Moldova State University in the typical chernozems in the areas not included in the arable circuit humiferous detritus content, consists in 8-12% of the total organic matter content in the 0-5 cm layer.

Already in the layer 15-25 cm humiferous detritus content is reduced to 3-5% from the organic substance content.

In the AmB horizon (45-68 cm) the humiferous detritus content is reduced to 1.18% of the total organic content (Table 1).

Table 1. Composition of the organic material in the fallow the arable and chernozems (Codru, Chișinau, MSU Biological Station, 1990-1994)

| Soil | Depth, cm | Content C org, total, % | Content C detritus, % from C tot | Soil | Depth, cm | Content C org, total, % | Content C detritus, % from C tot |
|---|---|---|---|---|---|---|---|
| Typic moderate deep humus chernozems fallow | 0-5<br>5-15<br>15-25<br>30-40<br>45-60 | 5.81<br>5.37<br>4.89<br>4.56<br>3.96 | 12.0<br>6.0<br>5.1<br>3.3<br>1.18 | Typic moderate deep humus chernozems arable | 0-5<br>5-15<br>15-25<br>30-40<br>45-60 | 4.96<br>4.37<br>3.58<br>2.98<br>2.33 | 2.98<br>1.87<br>1.58<br>1.98<br>1.73 |
| Typic moderate deep humus chernozems fallow | 0-5<br>5-15<br>15-25<br>30-40<br>45-60 | 5.28<br>4.63<br>4.21<br>3.38<br>2.86 | 8.3<br>5.1<br>3.8<br>2.6<br>1.2 | Typic moderate humus chernozems arable | 0-5<br>5-15<br>15-25<br>30-40<br>45-60 | 4.20<br>3.86<br>3.12<br>2.67<br>2.13 | 2.60<br>1.83<br>1.54<br>2.28<br>1.96 |

In the arable layer of the typical deep humus chernozems, the humiferous detritus is reduced to 2.60-2.98% of the humiferous detritus content which increases compared with deep effervescent chernozems.

This allows us to conclude that the crops develop deeper root system. At the same time, arable soils in the AB horizon create less favorable conditions for the decomposition of vegetal debris.

Even more the plant residues of the crop plants harder are decomposed. The same laws are found in case of typical moderate humifer chernozems but with other expression value. In the soil a unidirectional trend is established in the sense of reducing the humus content and its compliance with newly created condition by the landscape (Table 2).

Table 2. Dynamics of surfaces with different levels of humus assurance in some pedogeographic districts (% of the district)*

| Pedogeographic district, no | Predominant soil | Evaluation period | Degree of humus insurance | | | | |
|---|---|---|---|---|---|---|---|
| | | | Very low | Low | Moderate | Optimum | High |
| 1. | Gray soils, argilo-clay chernozems and levigated | 1965-1970 | 0.5 | 23.3 | 63.6 | 10.1 | 2.5 |
| | | 1970-1975 | 1.0 | 18.7 | 57.6 | 17.2 | 5.4 |
| | | 1975-1980 | 1.6 | 14.1 | 51.6 | 24.3 | 8.4 |
| | | 1980-1985 | 1.8 | 13.3 | 41.2 | 35.6 | 1.1 |
| | | 1985-1990 | - | 17.0 | 37.3 | 44.7 | 1.0 |
| 2. | Typic moderate humus chernozems | 1965-1970 | 0.4 | 15.3 | 55.7 | 28.6 | - |
| | | 1970-1975 | 1.5 | 13.4 | 47.6 | 40.3 | 7.2 |
| | | 1975-1980 | 2.3 | 11.5 | 39.5 | 43.2 | 3.2 |
| | | 1980-1985 | 1.6 | 15.8 | 45.5 | 34.5 | 2.6 |
| | | 1985-1990 | 1.6 | 11.0 | 46.5 | 38.9 | 2.0 |
| 10. | Typic moderate humus chernozems and levigated | 1965-1970 | - | 18.8 | 54.6 | 26.6 | - |
| | | 1970-1975 | 2.6 | 21.8 | 50.0 | 15.6 | - |
| | | 1975-1980 | 4.6 | 24.9 | 55.4 | 15.1 | - |
| | | 1980-1985 | 10.2 | 40.2 | 41.8 | 4.8 | - |
| | | 1985-1990 | 16.9 | 43.4 | 36.5 | 3.2 | - |
| 5. | Typic moderate humus chernozems and levigated | 1965-1970 | - | 19.4 | 62.7 | 17.9 | - |
| | | 1970-1975 | 8.3 | 29.1 | 50.1 | 12.5 | - |
| | | 1975-1980 | 9.4 | 38.9 | 43.7 | 7.1 | - |
| | | 1980-1985 | 12.5 | 44.8 | 38.1 | 4.5 | - |
| | | 1985-1990 | 13.6 | 34.9 | 47.6 | 3.9 | - |
| 9. | Levigated chernozems, argilo-clay and gray soils | 1965-1970 | - | 22.7 | 55.8 | 21.5 | - |
| | | 1970-1975 | 4.3 | 28.6 | 50.3 | 16.8 | - |
| | | 1975-1980 | 9.0 | 35.0 | 43.9 | 12.1 | - |
| | | 1980-1985 | 8.5 | 36.2 | 45.3 | 9.8 | - |
| | | 1985-1990 | 11.0 | 43.0 | 46.7 | 9.3 | - |
| District II a | Typic low humus chernozems | 1965-1970 | 1.4 | 18.7 | 58.5 | 20.3 | 0.6 |
| | | 1970-1975 | 4.2 | 19.3 | 53.2 | 21.9 | 1.3 |
| | | 1975-1980 | 6.0 | 19.8 | 46.0 | 23.0 | 5.2 |
| | | 1980-1985 | 8.9 | 35.1 | 52.0 | 3.9 | 0.8 |
| | | 1985-1990 | 8.1 | 30.9 | 56.5 | 4,5 | - |
| District 13 b | Carbonated chernozems | 1965-1970 | 5.0 | 41.5 | 45.1 | 6.6 | 1.8 |
| | | 1970-1975 | 20.0 | 42.0 | 30.1 | 6.3 | 1.6 |
| | | 1975-1980 | 22.9 | 42.9 | 27.1 | 5.5 | 1.8 |
| | | 1980-1985 | 18.8 | 44.0 | 29.7 | 5.6 | 0.9 |
| | | 1985-1990 | 19.4 | 51.5 | 28.0 | 1.0 | - |

*from the archive of Republic Center of Applied Pedology

Quantitative expression of its trend varies in time and space in accordance with pedogeographic conditions and concrete landscape conditions (Table 3).

The data presented in the Tables 2 and 3 highlight the fact that the intensive humus content in the chernozems, in the region, is reduced in the first 15-20 years after the intensive agricultural circuit (about 50-60 of humus losses return to this period). During this period, humus reserves are reduced as a result of mass mineralization of the humiferous detritus driven to disturbance of climate bioenergetic state of chernozems in the region. Later (around 10-15 years) humus reserves are reduced more slowly as a result of the reduction in the content of humic labile substances determined by the decrease in content of fresh energy sources in the soil, disturbing the dynamics of the formation and accumulation process of humus, worsening composition and quality of organic residues.

Table 3. State and dynamics of humus content in agrolandscape in Moldova in the period 1965-2013 (%)*

| Agricultural unit | No. Field | Predominant soil | Evaluation period | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1965-1970 | 1970-1975 | 1975-1980 | 1980-1985 | 1985-1990 | 2003-2013 |
| Agrosfera BM Nisporeni | 1 | Typic chernozems silty clay | 4.9 | 4.5 | 4.5 | 4.2 | 4.1 | 4.1 |
| | 2 | Typic chernozems silty clay | 5.1 | 4.7 | 4.6 | 4.4 | 4.1 | 4.1 |
| | 3 | Typic chernozems with solonetz area | 4.9 | 4.6 | 4.3 | 4.3 | 4.3 | 4.0 |
| | 4 | Typic chernozems with eroded areas | 3.8 | 3.4 | 3.0 | 3.1 | 3.0 | 2.9 |
| | 5 | Typic chernozems with eroded areas | 4.1 | 3.8 | 3.5 | 3.2 | 3.0 | 2.9 |
| Vindex agro Orhei | 1 | Typic chernozems silty clay | 5.3 | 4.9 | 4.6 | 4.3 | 4.2 | 4.0 |
| | 2 | Typic chernozems loamy | 5.1 | 4.7 | 4.6 | 4.4 | 4.2 | 4.0 |
| | 3 | Typic chernozems loamy | 4.9 | 4.6 | 4.3 | 4.6 | 4.3 | 4.0 |
| Podgoreni, Cantemir | 1 | Typic low humus chernozems, low-moderate erodated | 3.6 | 3.3 | 2.9 | 3.1 | 3.0 | 2.9 |
| | 2 | Typic low humus chernozems, low erodated | 3.9 | 3.6 | 3.4 | 3.1 | 3.0 | 3.0 |
| | 3 | Typic low humus chernozems, moderate erodated | 2.8 | 2.4 | 2.1 | 2.0 | 1.9 | 1.9 |
| | 4 | Typic low humus chernozems, low-moderate erodated | 3.7 | 3.4 | 3.1 | 3.1 | 3.0 | 2.9 |
| Mevil-Agro, Ocniţa | 1 | Typic chernozems silty clay | 5.7 | 5.3 | 5.1 | 4.7 | 4.5 | 4.4 |
| | 2 | Typic levigated chernozems silty clay | 5.9 | 5.5 | 5.2 | 5.0 | 5.0 | 4.7 |
| | 3 | Typic chernozems silty clay, low-moderate erodated | 5.5 | 4.6 | 4.3 | 4.2 | 3.9 | 3.8 |

*from the archive of Republic Center of Applied Pedology

Reducing humus reserves at this stage leads to the initiation of soil mass disintegration processes, which affected the reproduction process of the clod and the grainy structure; in particular of aggregate with a diameter of 3-1 mm, with an increase in aggregate content 1.0-0.25 mm. This led to intensification of both water and wind erosion.

During 40-45 years the chernozems in the region under conditions with relief elements <2° in the agricultural regime comparative with humus reserves in the fallow soils were reduced by 20-30%. In case of cereal crops humus losses make up 20-25% and in the hoeing and technical 25-30%.

In the erosion slopes humus losses reach up 30-40%. The first generalization of evolutionary laws of the organic matter system of the chernozems in the region shows that the components of the agricultural system differently influence the organic substances system (Jigau, 2016; Jigau and Tofan, 2016):

- Crop structure and the duration of their rotation influences the humus detritus content;
- The fertilization system influences the content and composition faction of labile humus;
- For the bioclimatic conditions in the Prut-Nistru space optimal values of ratio C:N=10-12:1. Lower values indicate unproductive losses of nitrogen; higher values denote nitrogen deficiency to carry out humification processes.

Tillage systems influence the content and composition of humiferous detritus and labile humus substances.

According to calculations by Masyutenko et al. (2008) within existing agricultural system under traditional crop rotation over 100 years the humus reserves in the chernozems will be reduced by 26%, over 200 years by 42% and over 500 years with 62%.

In the ameliorative crops rotation the evolution of humus means reducing humus reserves over 100 years with 12%, over 200 years with 20%, over 500 years with 29%. In the context of the exposed ones the bioenergetic state of the chernozems in the region can be evaluated by the parameters presented in the Table 4.

In the context of the parameters presented in the Table 4 their lower limits represent the value below which crops are significantly reduced and the reproductive capacity of the soil ecosystem resources.

Table 4. Bioenergetic parameters of the chernozems of the Prut - Nistru space

| Fertility factors | Normative for fertility levels | | |
|---|---|---|---|
| | Low | Moderate | High |
| Humus content in the horizon Am, % | <4 | 4-6 | >6 |
| Layer thickness to achieve the process of humus formation (Am+AmB), cm | <50 | 50-65 | >65 |
| The thickness of humus layer (A+B), cm | <60 | 60-80 | >80 |
| Humus reserves, t/ha layer 0-100 cm | <350 | 350-500 | >500 |
| Ratio C:N in composition of humus | >13:1 | 10-13:1 | ≤10:1 |
| Ratio Cah:Caf | <1.4 | 1.4-2.0 | >2.0 |
| The content of mobile humus substances, mg C/100 g of soil | 100-200 | 200-300 | 300-400 |
| Variation intervals of the content of labile humus substances, mg C/100 g of soil | 90-170 | 170-271 | 271-393 |
| Limit values for accumulation of humus, % | 4.0-4.5 | 6.5-7.0 | 8.0-8.5 |
| The content of organic substances easily decomposed into the arable layer, % soil mass | 0.35-0.55 | 0.55-0.8 | 0.8-1.2 |

Maximum values (upper limit) are the economically and ecologically justified values of reproductive activities for bioenergetic parameters. The assessment of bioenergetic parameters of chernozems in the region implies the use of two indicators: critical humus content and state allowable limit.

Critic content represent the amount of humus below which physical features (agronomic and environmental) can still be reproduced. This is 4.0%. Allowable limit of humus content (≈3%) under which a number of physical parameters (apparent density, structural-aggregate state, parameters of the porous space, hydro-physical parameters) show values that are characteristic of parental substrates (parental rocks).

In conditions when the humus content falls below the critical level in the soil evolution occurs super-cultivation state, accompanied by destructive elemental process, destructuring and intensive compacting due to intensive use under low flux condition of energy sources (humus sources).

In case when the humus content in soil falls below the allowable limits starts desertification processes in soils. In this context applying humus content and its inherent bioenergy parameters as an evolutionary indicator of chernozems, we find that the contemporary process of humus formation maintains the biogeosystem in the region in a state of energetic stagnation and retain the ability to respond to energy inputs.

This implies the conclusion that to ensure the sustainability of materialized chernozems in the extended reproduction for their bioproductive function is necessary to restore the priority role of the humus formation process.

In the context of adaptive-landscape-ameliorative technologies, based on the efficient combination of biological and technological methods that support the typogenetic processes of chernozems formation by using sources of organic matter added to the soil, implementation of ameliorative crops and conservative rotational system of soils, the use of bio and pedo-rotated fertilization system, supporting biochemical processes in soils by applying biohumic preparations.

In the sustainable management of chernozems emphasis has to be placed on management and control of substance transformation processes and interactions between them in the pedogenic process by practicing biofertilizers. These are preparations which are administered in soils in smaller amount that manure as catalysts which influence the processes of decomposition-transformation of organic and mineral substances and targeted to support the functioning process in soil microbiocenoses, efficiency, the humus formation process and the organic-mineral reactions responsible for the structural-functional soil organization.

The technologies developed in the Scientific Research Laboratory Pedogenetic Process of MSU in collaboration with SRL "AXEDUM", the emphasis is placed on the use of Biohumus and Biovit bioorganic preparation. The latter represents the fraction of the labile humic substances resulting from technological process for obtaining Biohumus. Except compost Biohumus and Biovit represents the biologic active substances (Table 5 and Figure 1).

In the Biovit's composition about 67-84% from the total biomass return to the active microbial biomass.

Table 5. Content of macro and microelements in Biohumus

| Indices | Unit of measure | Values indices | |
|---|---|---|---|
| | | In the natural | In the dry |
| pH | % | 7.8 | - |
| Ash content | | 69.7 | 46.6 |
| Organic substance content | | 30.3 | 53.4 |
| Total nitrogen content | | 0.88 | 1.55 |
| Ammoniac nitrogen content | | abs | abs |
| $P_2O_5$ content | | 0.97 | 1.70 |
| $K_2O$ content | | 1.05 | 1.85 |
| $N\text{-}NO_3$ content | mg/100 g | 608.7 | 1071.6 |
| Calcium content | moli/100 g | 19.0 | - |
| Magnesium content | | 22.0 | - |
| Mobile copper content | mg/kg | 1.16 | 2.05 |
| Mobile zinc content | | 4.30 | 7.60 |
| Mobile manganese content | | 5.30 | 9.30 |
| Mobile iron content | | 3.00 | 5.30 |
| Colonies of microorganism/1 g | | 20000 billions | |

The catalytic potential of Biohumus and Biovit is achieved only in the presence of fresh organic matter. It is better to use them in installments. In this respect, research has shown that the use of biohumic preparation in installments ensures that organisms that decompose humus are reduced 2-3 times (13 versus 39-44%) compared to administration of the same amount of biochemical preparation in a single rate. At the same time, their administration leads to intensification to a series of pedogenetic processes:

- Formation and accumulation of humus;
- Micro and macro-structuring of soils;
- Intense decomposition processes of organic residues and nitrification (Figure 1).

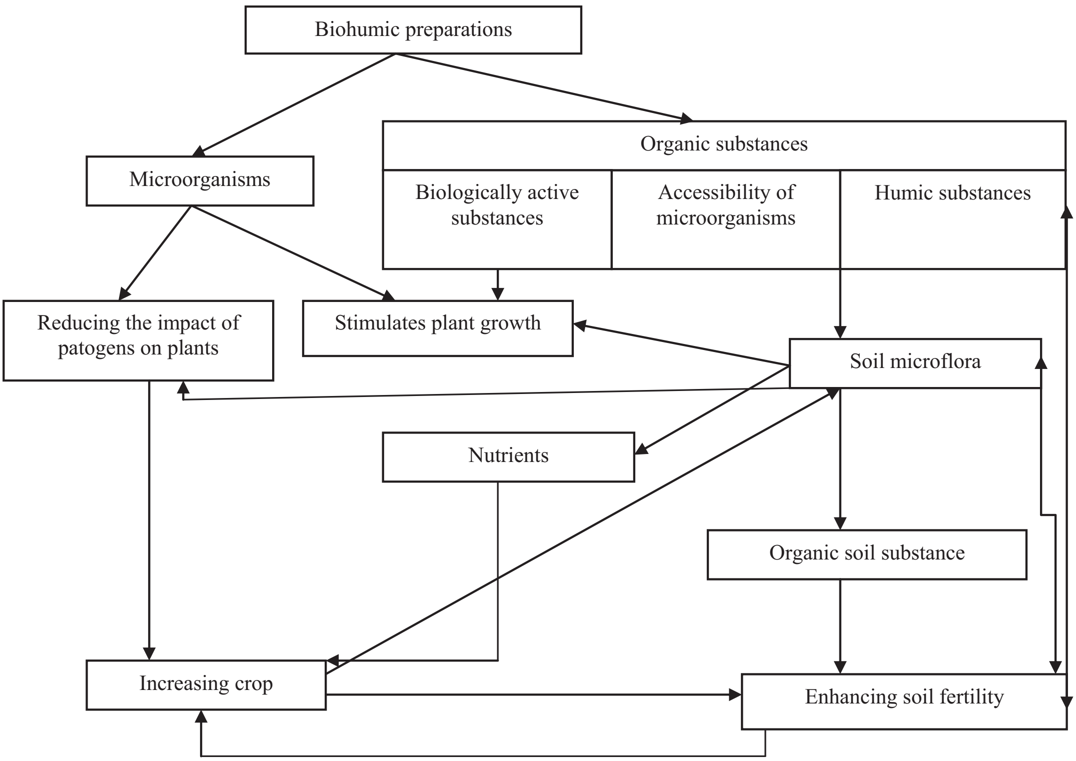


Figure 1. Mechanisms of polyfunctional action of biohumic preparation on soil-plant relations

## CONCLUSIONS

The pedogenesis regimes induced in chernozems by agrogenic changes and climatic conditions in phase change have reduced the priority role of the humus formation process in the evolution of the chernozems in the space between Prut and Nistru.

This severely affects the structuring process and the extent of pedogenesis on the descendant with the concentration on the elementary processes in the agrogenic layer. Therefore, the chernozems in the region are in a stagnant evolutionary phase being extremely vulnerable to various degradative processes.

Ensuring the chernozems sustainability can be achieved within a complex technology based on typogenetic processes: humus formation and accumulation, biogenic accumulation, structuring and migration of carbonates.

## REFERENCES

Jigau Gh., Tofan E., 2016. The pedofunctional framework for ensuring adaptive-landscape-ameliorative technologies. Scientific Papers, Series A, Agronomy, Vol. LIX, pp. 83-88.

Jigau Gh., 2016. Landshaftno-ekologicheskiye predposylki orosheniya chernozemov v Moldove. Lider Agro April, No. 4(66).

Masyutenko N.P., Kogut B.M., Kiseleva O.V. et al., 2008. Struktura chernozema tipichnogo i soderzhaniye organicheskogo ugleroda i labil'nykh gumusovykh veshchestv v pochvennykh agregatakh, Ros. akad. s.-kh. nauk, Vseros. nauch.-issled. in-t zemledeliya i zashchity pochv ot erozii, Pochv. in-t im. V.V. Dokuchayeva, Kursk, 34 s.