EVOLUTION AND GENESIS OF SOILS

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FORECASTING THE LEVELS OF CHEMICAL ELEMENTS CONTENT IN SOILS OF DIFFERENT GENESIS FOR THE ASSESSMENT OF THEIR ECO-ENERGY STATUS

Abstract. Grounded the new elaborated method for predicting of trace elements (TE) and heavy metals (HM) content in the soils of different genesis, which was elaborated by analysis the indicators parameters of their organic matter and energy characteristics in different natural-climatic zones of Ukraine, also of contaminated and intensive fertilizer soils. The method aims for the assessment of soils ecological-energy state due to the installation of the new natural relations of indicators humus, energy and elemental status of soils of different types, as a result, expanding the range of diagnostic indicators with identifing their paired combinations and simultaneously increasing of informativeness, accuracy, express testing of chemical elements (TE, HM) predicting levels, energy and humus state of soils to predict and ecological regulation of their quality.

The essence of the elaborated utility model – by the identify of new patterns of soil properties indicators and receive four matching pairs of humus (C_{GA}/C_{FA}, C_{total}), elemental and energy state (calorific value of humus, the reserves of energy in the soil layer of 0–20 cm) as soil indicators with the using of mathematical-statistical analysis of the obtained regression equations for the accurate determination is predicted the TE and HM content in soils of different types of background conditions, with the distribution algorithm of the method for different soil types in certain climate zones in the conditions of technogenic pollution and technological load, risk and the presence of man-made pollution to make timely management decisions. Elaborated method ensures the rapidity of the assessment and improves the accuracy of the TE/HM status prediction, energy and humus state of soils of different genesis with the identification of soils ecological differences to predict their quality by assessment of ecological functions for the ranking of energy intensity indicators of the soil.

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The method is applicable in the environmental regulation of TE and HM content, regulation of the loads (technogenic, technological) on a soil system, agroecology to address issues of biological agriculture, bio-energy and energy of soil formation; monitoring the quality of humus and the status TE and the dangers of excess accumulation of HM, in the soil humus indicators and /or energy state; efficient environmental management of soils, both in background conditions and with different anthropogenic impacts and in the research practice.

Grounded the method was examined on the of soils simples in different natural-climatic zones of Ukraine, contaminated soils in Kharkiv, Donetsk and Lugansk regions, and intensive fertilizer (organo-mineral, organic and mineral system of fertilizers) of soils in Kiev, Kharkiv, Poltava and Lviv region.

Key words: *soil, trace elements, heavy metals, energy capacity, the calorific value of humus, the reserves of energy in the layer 0–20 cm, technogenic pollution, technological load, method, prediction, matching pair of indicators*.

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ПРОГНОЗУВАННЯ РІВНІВ ВМІСТУ ХІМІЧНИХ ЕЛЕМЕНТІВ У ҐРУНТАХ РІЗНОГО ГЕНЕЗИСУ ДЛЯ ОЦІНКИ ЕКОЛОГО-ЕНЕРГЕТИЧНОГО СТАТУСУ

Анотація. Обґрунтовано спосіб прогнозування вмісту мікроелементів (МЕ) та важких металів (ВМ) у ґрунтовій системі на прикладі обстежених ґрунтів різного генезису природно-кліматичних зон України, забруднених ґрунтів Харківської і Луганської областей й інтенсивно удобрених (органо-мінеральна, органічна і мінеральна системи удобрення) грунтів Харківської, Полтавської та Львівської областей.

За рахунок встановлення нових взаємозв'язків та отримання чотирьох діагностичних комбінаційних пар показників гумусового, елементного та енергетичного стану (теплотворна здатність гумусу, запаси енергії в шарі до 20 см) ґрунту з використанням математико-статистичного аналізу та регресійних рівнянь прогнозують рівні вмісту МЕ/ВМ у грунтах різного генезису. Алгоритм способу поширено на ґрунти різних типів певної природно-кліматичної зони за умов техногенного забруднення і технологічного навантаження.

Установленням нових закономірних зв'язків показників базових властивостей ґрунтів забезпечується розширення спектру діагностичних показників з одночасним підвищенням інформативності, точності, експресності прогнозування рівнів умісту МЕ/ВМ, оцінювання еколого-енергетичного стану грунтів різних типів за фонових умов, впливу технологічного навантаження, ризику і наявності техногенного забруднення для оцінювання та нормування якості грунтів. Спосіб може знайти застосування в екологічному нормуванні вмісту МЕ/ВМ та нормуванні навантажень (техногенних, технологічних) на ґрунтову систему, агроекології за вирішення питань біологічного землеробства, біоенергетики та енергетики ґрунтоутворення; моніторингу якості гумусу і статусу МЕ та небезпеки надлишкового накопичення ВМ у грунтах за показниками гумусового та/або енергетичного стану; ефективного екологічного менеджменту ґрунтів за прийняття своєчасних управлінських рішень та одночасної мінімізації витрат ресурсів як за фонових умов, так і за різних антропогенних впливів та в науково-дослідній практиці.

Ключові слова: *ґрунт, мікроелементи, важкі метали, енергоємність, теплотворна здатність гумусу, запаси енергії в шарі до 20 см, техногенне забруднення, технологічне навантаження, спосіб, прогнозування, комбінаційні пари показників.*

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ПРОГНОЗИРОВАНИЕ УРОВНЕЙ СОДЕРЖАНИЯ ХИМИЧЕСКИХ ЭЛЕМЕНТОВ В ПОЧВАХ РАЗЛИЧНОГО ГЕНЕЗИСА ДЛЯ ОЦЕНКИ ЭКОЛОГО-ЭНЕРГЕТИЧЕСКОГО СТАТУСА

Аннотация. Обоснован способ прогнозирования содержания микроэлементов (МЭ) и тяжелых металлов (ТМ) в почвенной системе на примере обследованных почв разного генезиса природно-климатических зон Украины, загрязненных почв Харьковской и Луганской областей и интенсивно удобренных (органо-минеральная, органическая и минеральная системы удобрения) почв Харьковской, Полтавской и Львовской областей.

За счет установления новых взаимосвязей и получения четырех диагностических комбинационных пар показателей гумусового, элементного и энергетического состояния (теплотворная способность гумуса, запасы энергии в слое до 20 см) почвы с использованием математико-статистического анализа и регрессионных уравнений прогнозируют уровни содержания МЭ/ТМ в почвах разного генезиса. Алгоритм способа экстраполируют на почвы различных типов определенной природно-климатической зоны в условиях техногенного загрязнения и технологической нагрузки.

Установлением новых закономерных связей показателей базовых свойств почв обеспечивается расширение спектра диагностических показателей с одновременным повышением информативности, точности, экспрессности прогнозирования уровней содержания МЭ/ТМ, оценки эколого-энергетического состояния почв разных типов при фоновых условиях, влияния технологической нагрузки, риска и влияния техногенного загрязнения для оценки и нормирования качества почв. Способ может найти применение в экологическом нормировании содержания МЭ/ТМ и нормировании нагрузок (техногенных, технологических) на почвенную систему, в агроэкологии для решения вопросов биологического земледелия, биоэнергетики и энергетики почвообразования; мониторинга качества гумуса и статуса МЭ и опасности избыточного накопления ТМ в почвах по показателям гумусового и/или энергетического состояния; эффективного экологического менеджмента почв для принятия своевременных управленческих решений и одновременной минимизации затрат ресурсов как в фоновых условиях, так и в различных антропогенных воздействиях, а также в научно-исследовательской практике.

Ключевые слова: *почва, микроэлементы, тяжелые металлы, энергоемкость, теплотворная способность гумуса, запасы энергии в слое почвы 0–20 см, техногенное загрязнение, технологическая нагрузка, способ, прогнозирование, комбинационные пары показателей.*

INTRODUCTION

Prediction of the quality of different genesis soils is complex and multi-stage task in solving on background conditions and anthropogenic (technogenical, technological) impacts on soils (Medvedev, Plisko, 2003; Medvedev, 2012). For prediction the environmental impact of loads on soils patterns of pollutants migration and transformation in the separate links of trophic chains and patterns of soils ecological status (quality) changed under the influence of anthropogenic loads are to be used (19 th World Congress of Soil Science, 2010; Glazovskaya, 1997; Izrael, 2001; Kovda, 1973; Kovda, 1974; Lal, 2007; Lobell, Burke, Tebaldi, 2008). Models provide to get predictive estimates of changes in the elemental status of the soil-plant system, other links of trophic chains, about degradation of different genesis soils with the account of transport processes, the translocation of pollutants and their accumulation; concerning physical, chemical and biological transformation and decontamination; as to changes of properties and functions of soil that are the basis for the environmental regulation and assessment of their quality due to the background conditions and the impact of technological loads, industrial pollution (Glazovskaya, 1997; Lal, 2007; Lobell, 2008; Revich, 2007; Samokhvalova, Fateev, 2006; Pat. Ukrajiny na vynaxid № 83563 UA, 2008).

The application of eco-energy indices of different genesis soils, as integral characteristics of changes their properties, is an important component of predicting changes in their functions (Kovda, 1973; Kovda, 1974; Volobuev, 1974, 1982, 1983; A.c. 1481681 A1 SU, 1989). However, the forecasting is constrained by the fact that it is difficult to consider probabilistic component, which is detected by investigation of the ecological state of soil, effects and precise patterns of developing soil processes, random component of soil processes that are virtually impossible to predict and is an extremely difficult methodological issue. Therefore, the specificity of the ecological state prediction of the soil affects a significant decline in the quality of forecasts.

The elaboration of methodological approaches for predicting of the different genesis soils element status by using of their eco-energy state indicators and implementation is an urgent problem that requires further improvement of prediction existing methods, for clarification forecasts and forecast models.

Relevant for prediction of soil quality is the investigating for new diagnostic criteria for assessment using indicators of trace element status, humus (C_{total}, %; ratio of $C_{humic\ acids}$ / $C_{fulvic\ acids}$) and energy state (generalizing characteristics of the intensity of energy content in organic matter of the soils – specific internal energy of humus or calorific value, the total energy reserves in the layer of 0–20 cm). Simultaneously actualized the necessity for selective choice of the most suitable diagnostic and correlation of related pairs of soil properties suitable indicators the using of which is based on the possibility to accurately express and forecasting environmental and energy status of different genesis soils and their quality taking into account the elemental composition.

The feasibility of using a set of soils ecological and energy status indicators for predicting elemental status due to their high information content and the predictability of the results due to their close connection and the possibility of combining various indicators of the soils biological processes intensity (microbiological and biochemical activity, decomposition and synthesis of organic compounds etc.) into generalized terms of its energy state and for correctly determine the direction of the substances and energy transformations in the soils.

The complex of soils humus and energy condition indicators allows justify effective using of management techniques of the soil quality control for quantitative evaluation of soil processes due to the background conditions, technological loads and technogenic pollution. In addition, soil organic matter is an accumulator and distributor of solar energy. Therefore, the using of soil energy intensity indicator can be used as generalized criterion of its functioning, to reflect the productivity of the soil, the intensity of the processes of humification-mineralization, to serve as an indicator of soil system stability. Thus, in the case of dynamic equilibrium (equivalency of the receipt and consumption energy process of soil organic matter) the entropy is close to the minimum indicating the lack of energy storage in soils humus.The stability of the humification-mineralization processes in a soil system determines the soil ability to recover energy resources due to the accumulation and distribution of energy generated by photosynthesis (Kovda, 1974; Volobuev, 1974, 1982, 1983; Volodin, Phedorchenko, Birukova, 1989). Rational use of the soil energy is the conservation and restoration of its basic fertility and, consequently, soil system eco-energy state. Therefore, using of soil humus indicators and/or energy state allows more complete account of soils properties and functions, and thus of soil resources; reducing the cost of anthropogenic energy and elimination of negative impacts on soil environmental and energy state by using of less energy-intensive measures to restore the soil functions for the existence of degradation processes. All of the above actualizes the necessity to predict of soils quality, determination the new criteria and indicators for assessing their quality based on its trace element status, humus and energy state, including the technological lods, risk and availability of technogenic pollution.

The purpose of the investigation – to elaborate a method for predicting levels of chemical elements content in soils of different genesis for the assessment of their ecological-energy state due to the installation of the new natural relations of indicators of humus, energy and elemental status of soils of different types, as a result, expanding the range of diagnostic indicators with identifing their paired combinations and simultaneously increasing of informativeness, accuracy, quick testing of chemical elements predicting levels, energy and humus state of soils to predict and ecological regulation of their quality.

MATERIALS AND METHODS

The elaborations of a method include:

1. Conducting of patent researches due to the DSTU 3575 and DSTU 3576. Objects – the copyrights that are patented in Ukraine and the CIS countries in the plane of the goal. Subject of researches – the method in general; separate operations (stages) of the method that are patentability; methods for their preparation and scope of application; the equipment used in carrying out the process; methodological approaches to predicting of the different types of soils element status, including the influence of technogenic HM pollution and technological loads; methods of humus and energy status of the soil predicting by using the methods of mathematical modeling, including models of transport and transformation of pollutants (geographic model) and the models of soils state changes by the impact of soil contamination (environmental models); methods of extrapolation and expert estimates. Research methods – methods of theoretical analysis, systematic approach.

2. Field stage – soil – geochemical investigations, including, in conditions of technological loading on the soils of Kyiv, Kharkiv, Poltava and Lviv regions and in conditions of constant impact of inorganic nature pollutions of atmotehnogenic emission sources in Kharkiv region and of industrial facilities in Donetsk and Luhansk regions; carrying out a series of stationary microfield experiments. Objects of research – the soils of Forest-Steppe and Steppe natural-climatic zones of Ukraine for the effects of HM pollution and concealed in its absence. Research methods – universal general scientific methods, ecosystem and landscape-geochemical approaches.

The investigations of natural connections of indicators of trace elements, energy and humus status of different genesis soils and therefore indices of soil properties were carried out with sampling of arable (0–20 cm) layer. Soil-geochemical researches of HM pollution impact on soils performed due to the conditions of constant and periodic exposure of polyelemental pollution sources Zmiev TPP PJSC "Centrenergo" NJSC "Energy Company of Ukraine» in Kharkiv region, OJSC "Ukrtsynk" and OJSC "Avdeevka Coke Plant" in Donetsk region; industrial facilities in Lugansk and Bilokurakynsky, Perevalsky, Slavyanoserbsky, Trojtsky district of Lugansk region. Also, to confirm idea for the new technical elaboration were used HM data content in the soils from the Ecological Atlas of Kharkiv (2005), Donetsk (2007) and Lugansk (2004) regions.

Field researches on technological loads carried out in conditions of stationary experiences of the Soil Science, Agriculture and Agrochemistry Department of Lviv National Agrarian University, Western Forest-steppe of Ukraine. Explored the effectiveness of organo-mineral, organic and mineral fertilizing systems installed in established effective ratio amount combinations of soils improvers for the HM mobile forms immobilization and the activation of TE in soil with sampling of soil samples and establishing patterns change their content and dynamics of humus status and transformation of organic matter in the dark-grey soil (Greyic Phaeozems Albic, WRB 2006) of a field crop rotation.

The energy intensity of different granulometric composition chernozem soils due to the influence of the fertilizers systems are determined in long term field experiences in Kyiv (Myronivska ES), Kharkiv (EF Grakovo), Poltava (Poltavska ES) and Lugansk (Lugansk ES) regions. Used mineral, organic and organo-mineral system of fertilizers was balanced by the introduction of the basic nutrients of supply. The application of organic and mineral fertilizers optimal doses was carried out for the using of current guidelines (Vlasiuk, Dmytrenko, 1962) according to the soils type and climatic conditions of a particular zone (The Handbook: Fertilizers and their using, 2010).

3. Analytical stage – in samples of different types of soils (sod-podzolics (Umbric Albeluvisols Abruptic, WRB 2006), light-gray (Greyic Phaeozems Albic), gray (Greyic Phaeozems Albic), dark-gray (Greyic Phaeozems Albic), chernozems podzolized (Luvic Phaeozems Albic), chernozems typical (Voronic Chernozems pachic), chernozems ordinary (Voronic Chernozems Pachic) and chernozems southern (Haplic Chernozems Pachic), chestnut (Haplic Kastanozems Chromic), dark-chestnuts (Haplic Kastanozems Chromic) soils, etc.) for laboratory analysis according to the applicable regulatory documents and methodological base were identified: a) the content of mobile forms of HM and TE (using extractant-ammonium acetate buffer, pH 4.8 and 1N HCl according to the DSTU 4770.1 – DSTU 4770.9: 2009 and MVV 31-497058-016-2003); b) the total content of organic matter – by Tyurin method (DSTU 4289:2004); c) the group composition (modified method by N. M. Kononova and N. P. Belchykova according to DSTU 7855:2015) and the fractional composition of soil humus (modified method by V. V. Ponomareva and T. A. Plotnikova according to DSTU 7828:2015); d) committed preparative allocation of soil humus substances (DSTU 7606:2014); e) the specific energy of the soil and of the humic acids preparations – using a calorimetric installation В – МА 08 ПУ 1.470.000 in terms of the specific heat of combustion of soil samples according to DSTU 7866:2015; f) the density of the soil structure on background conditions, the impact of technogenic pollution and technological load according to DSTU ISO 11272-2001.

4. Cameral stage – evaluation of soils trace elements status due to the expert assessment normative-reference documents, the calculation of the total energy reserves of humus in the soil, statistical data processing of the obtained data of humus, energy state of soil including the influence of technological loads, industrial pollution with the construction of mathematical models.

The calculation of the total energy reserves that accumulated by soil humus, as indicator of the energy status of soil, carried out by the known formula D. S. Orlova – L. A. Grishinoj (Orlov, Birjukova, Rozanova, 2004; Orlov, Grishina, 1981) in modification by O. L. Orlov (Orlov, 2002) taking into account the quality of the humus and heat capacity of its main fractions:

$$Q = (19{,}96 * C_{G\ acids} + 9.16 + 17.86 * C_{F\ acids} * G) * H * d * 10/100, \quad (1)$$

where Q – energy reserves accumulated by soil humus, 10^6 kJ / ha (or 10^3 MJ / ha); 19.96 – calorific value of humic acids, kJ / g; 9.16 – calorific value of fulvic acids, kJ / g; 17.86 – humic calorific value, kJ / g; $C_{G\ acids}$ – humic acid content, %; $C_{F\ acids}$ – fulvic acid content, %; G – humin content, %; H – soil layer, m; d – density of soil structure, g/cm^3; 10 – conversion factor of 10^6 kJ / ha; 100 – transfer units measurements of G_{acids}, F_{acids} and G to percentage.

Environmental assessment of soil on TE status and contents of the HM was performed according to the applicable regulations and methodological basis using the established background levels of TE /HM for soils in specific climatic zones of Ukraine (Fateev, Samokhvalova, 2012). Also, to confirm the idea for the elaboration of new method were used digital materials of scientific reports of the laboratory of soil protection from technogenic pollution NSC "Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky" on implementation of research works for 2001–2005, 2006–2010 relative to the element status of soils for the background soil conditions, the impact of technogenic HM pollution for their further generalization.

The analytical numerical data of the energy accumulative function of the soil humic substances – indicators of specific internal energy or calorific value of humus; the reserves of energy accumulated by soil humus, the microelement status and humic condition were statistically processed using the modules of correlation, variance, regression and factor analysis within *Statistica 10.0,* including calculations on the equations of linear, exponential and logarithmic regression.

RESULTS AND DISCUSSION

The generalization of the the soil-geochemical investigations results and analysis of the obtained data of TE /HM content in soils of different genesis in natural climatic zones of Ukraine (Samokhvalova, Fateev, Luchnykova, 2011) and determination of the humus group composition and total content of soils organic matter established (Samokhvalova, Lopushnjak, Fateev et al., 2014; Samokhvalova, Lopushnjak, Fateev et al., 2016) the close connection of the TE soils status and mobility of HM and TE content and total content of humus, group and fractional composition of organic matter, the level of hydrolytic acidity and content of physical clay in soils of a particular type. Established that the balance between the processes of mineralization and synthesis of organic compounds determined by sustainability of humic acids, stability over time of the $C_{\text{humic acids}}$ / $C_{\text{fulvic acids}}$ ratio (Pat. na korysnu model 95649 UA, 2014; Pat. na korysnu model 105444 UA, 2016; Samokhvalova, Lopushnyak, Fateev et al., 2015), the energy intensity of the soil (Pat. na korysnu model 107854 UA, 2016; Samokhvalova, Skrylnyk et al., 2015).

For polluted by HM chernozem soils it was determined an increase of soil organic matter mineralization intensity (Samokhvalova, Fateev, 2006). It was established the relationships mobility majority of TE / HM in soils of different genesis to fulvic acids contents without and due to the influence of HM as soils contaminats.

As a results of investigations conventional energy intensity of chernozem odinary (voronic chernozem, WRB 2006) were established that humus energy intensity in soil layer 0–10 cm is an average of 0,024 MJ / 1 g of humus, of the zonal soil – 0,021 MJ / 1 g of humus (agrocenosis) and 0,026 MJ / 1 g humus (virgin steppe). In the 10–20 cm layer of technogenic chernozem odinary on loess loam determined the reducing of energy intensity in 2,5–14 times according to the level of 0,0097–0,0017 MJ / 1 g of humus. Also established a direct dependence of the specific heat of combustion and the content of organic matter in technogenic soils (Zholudeva, Kovalev, Yehorenkova, 2010).

Using the index of soil total humus content (C_{total}, %) for predicting is limited. Becides the error in determining of its contents in soil (15–20 %), carbon content is characterized by spatial and temporal (1–3 years) with a range of volatility fluctuations $\pm$ 0.2–0.5 % abs. due to impact on its numerical value of content in soil of weather conditions, the amount of plant residues in the soil and etc. (Smirnov, Muravin, 1981).

Since the quality composition of the humus in the soil is different, energetic properties have separate soil phases, including mineral matter, soil microorganisms, chemical endo- and exogenous reactions of the soil, and the main part of the internal energy is the energy of the crystal lattice of minerals, therefore the application of energy principle is based on the understanding the necessity of taking into account all the "carriers" of soil energy (energy potential), the energy intensity of plants for the management of substance and energy transformations in the soil-plant system, thus rationing element status and control its quality. However, with substantial expenditure of resources for obtaining experimental data, and as a consequence, their failure prevents determining soils energy potential. Nevertheless, by the results of our researches (Lopushniak, 2012, 2013, 2014, 2015; Shedey, Shevchenko, 2006; Shedey, 2010; Skrylnyk, 2008, 2010; Zholudeva, Kovalev, Yehorenkova, 2010) it was established that determinations of soil energy intensity (calorific value of humus in the soil and the total energy stored in the 0–20 cm layer) are sufficient to assess changes in ecological and energetic status of different soil types due to the various systems of fertilization, controlled impacts on soil processes of mineralization-humification, reducing the free energy. Using indicators of ecological and energy state of a particular type of soil it is possible to effectively predict, assessment and regulate soils quality for their effective using and management.

On the basis of generalization of the obtained data of the soils elemental status of different natural climatic zones of Ukraine it was established that the effectiveness of predicting soil quality in terms of their ecological and energy status raises it for further use diagnostically suitable combinations of parameters energy and humus state of soils and the algorithm for their selective using, which is offered in methodical approach, ensures the technical result – increasing accuracy and predictability of the soil quality status; the express prediction of the soil element status for evaluation of environmental and energy state of soils of different types, including the impact of technological loads and technogenic pollution.

Analysis of the existing patent documentation indicates that close to the technical nature of the elaborated method is a known method of forecasting levels of Cu and Zn mobile forms in soil under anthropogenic load (Pat. na korysnu model 58720 UA, 2011), which involves calculation of the nitrogen and phosphorus ratio with the definition of the predicted content of metals mobile forms in the soil by regression equations.

The established disadvantages of this method are: a) decrease the functionality of its implementation and, accordingly, efficiency while reducing the predictive value of received data of the TE /HM content in different soil types due to the limited its application only on irrigated dark-chestnut soil and the impossibility of predicting the content of other elements in the soil, except for Zn and Cu; b) increased the risk of negative impact on the quality of organic matter of the soil, primarily podzolic line by increasing the mobility of organic compounds, their mineralization and degradation, simplification of the soils structure; c) increased mobility of metal pollutants in soil and their migration into the adjacent environment by the systematic application of physiologically acid fertilizers.

Another known method of the soil production functions express predicts on the determination of the soil energy potential and plant biomass by calorimetry (A.c. 1481681 A1 SU, 1989). The method involves the calculation by the formula the rate of soil fertility reproduction (γ) taking into account the energy potential of the soil covered with plants and without them, the period of plant vegetation. The value of this index predict enhanced ($\gamma > 1$), simple ($\gamma = 1$) the restoration of soil fertility or degradation ($\gamma < 1$). The main disadvantages of this method are: a) determining of accumulation intensity and energy consumption is needed for different periods of time in soils and growing different types of plants, which significantly increases the complexity and amount of time for the method implementation; b) according to the method of prediction expanded reproduction of soil fertility is possible due to the condition of availability in the soil total biomass of plants that is almost impossible and requires consideration of its exclusion, which also increases resource costs of method; c) the method allows the prediction of fertility only for soils, the increase of the energy potential for the vegetation period will not be less than 1 % of the initial value, which reduces the possibility of its application.

Closest to the implementation mechanism and achieved results is a method of predicting the soil TE availability by mathematical models (Pat. na korysnu model 89939 UA, 2014) with determining the carbon content of humic ($C_{G\ acids}$) and fulvic acids ($C_{F\ acids}$) and the ratio of $C_{G\ acids}$ / $C_{F\ acids}$ and the using of statistical and mathematical analysis to obtain the regression equations and, based thereon, determining the predicted content of TE / HM in the soil.

The disadvantages of the proposed method are: a) the limited using of the $C_{G\ acids}$ / $C_{F\ acids}$ index for determining the predicted content of TE / HM mobile forms, as in the evaluation of the TE sufficiency of soils and the dangers of HM excessive accumulation in soils for technogenic and technological loads (Samokhvalova et al., 2015) due to the impact on the $C_{G\ acids}$ / $C_{F\ acids}$ ratio uncontrolled content of TE / HM mobile forms in soils of different buffer properties (as the result of high natural spatial variability, which significantly increase in conditions of HM contamination, the application of organic and mineral fertilizers and different soils acidity, depending on the direction and development of soil-forming processes in individual differences and the types of soils and their granulometric composition); b) increase of HM mobility and soil organic matter content while the simultaneous imbalance of the humic and fulvic acids content, the decrease in the TE mobility by technogenic pollution of the soil, makes it impossible to correct using of the $C_{G\ acids}$ / $C_{F\ acids}$ ratio for solving the problem forecast of the HM and the TE content in the soils; c) the limited using of humus group composition to predict changes in its quality for intensive using of soils and, due to possible instability in time of the $C_{G\ acids}$ / $C_{F\ acids}$ ratio (Orlov et al.,1999, 2002, 2004); d) insufficient of the $C_{G\ acids}$ / $C_{F\ acids}$ ratio measure as a diagnostic and estimate due to varying intensity of humic acids and fulvic acids of soil organic matter as in background conditions (Tarariko, Nesmashna, 2000; Tarariko, Nesmashna, Lychuk, 2007) and the conditions of the technological load (Lopushniak, 2012, 2013, 2014, 2015; Shedey, Shevchenko, 2006; Shedey, 2010; Skrylnyk, 2008, 2010); e) the accuracy decrease in estimating of forecasts TE / HM content in the soil-plant system for using only $C_{G\ acids}$ / $C_{F\ acids}$ ratio (Samokhvalova, Lopushnjak, Fateev, 2014, 2015, 2016; Samokhvalova, Skrylnyk, Shedey, 2015, 2016). Thus, all the above mentioned to decrease in the predictive values of data of the TE / HM content in soils of different genesis and a simultaneous increase of the complexity and methods implementation resource costs, requires the elaboration of a method that will overcome the identified deficiencies.

As a result of the investigation of new diagnostic criteria for estimating of the soil quality we implemented the selection of the most diagnostically related and suitable soils properties, which proposed for combinational using for solving the problem of forecasting. Attracted combinations pair parameters of elemental status, humus (C_{total}, %; $C_{G\ acids}$ / $C_{F\ acids}$ ratio) and energy state (generalizing characteristics of the soil organic matter energy capacity intensity – specific internal energy of humus or its calorific value; the total energy reserves in the 0–20 cm layer). On the basis of their using is possible express accurately predict of the eco-energy state of different genesis soils and their quality, taking into account the elemental composition.

The algorithm of the elaborated methodological approach includes:

1. Sampling of soils (0–20 cm layer) of different types (sody-podzolic, light gray, gray, dark gray, etc.) and their chemical analytical analysis according to the standards and methodical base, framework guides of soils properties in Ukraine with determination of the soil parameters of elemental, humus and energy state indexes due to the background conditions, technological load and technogenic HM pollution: a) actual content of TE / HM; b) the total organic matter content; c) humus fractionally-group composition; d) preparative selection of soil humus substances and determination of the soil specific energy content and preparations of humic acids – on indicators of humus specific calorific value of soil samples; e) determining the soil humus total energy reserves in the layer of 0–20 cm, as an indicator of its energy state according to the well-known Eq. 1. The obtained results and reference data for soil of a certain type properties indicators bring to Table 1 and used as base for further calculations.

2. The investigations of natural connections of microelements, humus (C_{total}, %; ratio of $C_{G\ acids}$ / $C_{F\ acids}$) and energy state (soil organic matter energy capacity intensity – specific internal energy of humus or its calorific value; the total energy reserves in the soil layer of 0–20 cm) of different genesis soils on statistical data processing within *Statistica 10.0* package; used modules of correlation, variance, regression analysis; including calculations by the equations of linear, step and logarithmic regression.

Table 1

The parameters of humus, soil density, zinc content and energy intensity changing for the background soil conditions and the impact of technogenic and technological loads

Type of soil	C_{total}, %	$C_{G\,acids}$, %	$C_{F\,acids}$, %	G, %	d, g/cm^3	Actual content of Zn, mg/kg	Energy intensity of the soil: The calorific value of soil humus, MJ/kg	Energy intensity of the soil: Q, Total energy reserves in the soil layer of 0–20 cm, 10^3 MJ/ha	$C_{G\,acids}$ / $C_{F\,acids}$
1. In the absence of loads (background conditions)									
Sod-podzolic	0,9	0,17	0,2	0,53	1,5	1,69	0,106	0,44	0,85
Gray podzolic	1,2	0,27	0,3	0,63	1,5	1,92	0,188	0,58	0,90
Dark-gray	3,1	1,1	0,54	1,46	1,3	1,06	0,840	1,40	2,04
Chernozem podzolized	2,44	1,0	0,31	1,13	1,2	2,1	0,820	1,03	3,2
Chernozem ordinary	3,9	1,25	0,7	1,95	1,1	0,15	0,900	1,46	1,79
Chernozem typical	4,8	1,75	0,6	2,45	1,2	1,75	1,200	2,02	2,92
Chernozem southern	2,2	0,55	0,42	1,23	1,2	1,02	0,600	0,809	1,3
2. Due to the the technogenic load (HM pollution)									
Chernozem ordinary contaminated	2,08	0,38	0,5	1,2	1,22	54,3	0,790	0,81	0,76
Chernozem podzolized contaminated	1,9	0,2	0,4	1,3	1,21	68,5	0,650	0,74	0,5
Sod-podzolic contaminated	0,79	0,1	0,2	0,49	1,52	83,5	0,090	0,37	0,5
3. Due to the the technological load (application of different fertilizer systems)									
Chernozem podzolized (control)	2,44	1,0	0,31	1,13	1,2	1,5	0,99	1,02	3,2
Chernozem podzolized (mineral fertilizer system)	2,38	0,93	0,29	1,16	1,2	2,0	0,80	1,00	3,21
Chernozem podzolized (organic-inorgenic fertilizer system)	2,46	0,99	0,30	1,17	1,2	0,9	0,98	1,04	3,3
Chernozem podzolized (organic fertilizer system)	2,45	0,94	0,34	1,17	1,2	3,0	0,93	1,03	2,76

3. Prediction of the TE / HM content in the soil, for example due to background conditions, by the equations of installed dependencies (mathematical models) after determining by the correlation analysis of matching pairs appropriate indicators of soil properties, for

example, predicted concentrations of zinc (C_{Zn}) in the soils of the podzolic series (sod-podzolic, light-gray, gray podzolic and dark-gray) are calculated from equations 2–5:

$$C_{Zn} = 2{,}92 + 3{,}72\ x - 1{,}59\ y \qquad (2)$$

$$C_{Zn} = 2{,}63 - 8{,}95\ z + 3.55\ y \qquad (3)$$

$$C_{Zn} = 2{,}10 - 1{,}33\ z + 0{,}42\ j \qquad (4)$$

$$C_{Zn} = 1{,}43 - 2{,}37\ x + 0{,}81\ j \qquad (5)$$

and chernozems series (chernozem typical, ordinary and southern) soils from equations 6–9:

$$C_{Zn} = 0{,}23 + 2{,}65\ x - 0{,}33\ y \qquad (6)$$

$$C_{Zn} = 2{,}43 + 9{,}46\ z - 4{,}12\ y \qquad (7)$$

$$C_{Zn} = -\ 0{,}07 - 0{,}57\ z + 0{,}90\ j \qquad (8)$$

$$C_{Zn} = 2{,}05 - 4{,}39\ x + 1{,}19\ j \qquad (9)$$

where C_{Zn} – predicted (calculated) zinc content in soil, mg/kg; x – calorific value of soil humus, MJ/kg; z – Q, the energy reserves in the soil layer of 0-20 cm, 10^6KJ/ha (or 10^3 MJ/ha); y – total content of humus, %; j – $C_{G\ acids}/C_{F\ acids}$ ratio.

With further spread of the algorithm of the method for soils of other specific types certain climatic zones in the conditions of technogenic pollution and technological loads; the visualization of the established dependences of soil properties indicators on the diagrams (Fig. 1, 2, 3) and in the format relevant equations and spreadsheets of the obtained data (Table 1–2). For example, set the levels of Zn content in soils of different genesis on the basis of existing linear dependences with indicators of C_{total} and calorific value of humus in the soil of a particular type (background conditions) on the relevant equations 2 and 6, characterized by the following equations for the soils of podzolic series (sod-podzolic, light-gray, gray podzolic and dark-gray, equation 2):

$$C_{Zn} = 2{,}92 + 3{,}72\ x - 1{,}59\ y$$

$$C_{Zn\ sod\text{-}podzolic\ soils} = 2{,}92 + 3{,}72 * 0{,}106 - 1{,}59 * 0{,}9 = 1{,}8;\ C_{Zn\ actual} = 1{,}7$$

$$C_{Zn\ dark\text{-}gray\ soils} = 2{,}92 + 3{,}72 * 0{,}840 - 1{,}59 * 3{,}1 = 1{,}1;\ C_{Zn\ actual} = 1{,}06$$

and chernozems series soils (chernozems typical, podzolized and southern) by the formula 6:

$$C_{Zn} = 0{,}23 + 2{,}65\ x - 0{,}33\ y$$

$$C_{Zn\ chernozems\ podzolized} = 0{,}23 + 2{,}65 * 0{,}820 - 0{,}33 * 2{,}44 = 1{,}5;\ C_{Zn\ actual} = 1{,}5$$

$$C_{Zn\ chernozems\ southern} = 0{,}23 + 2{,}65 * 0{,}6 - 0{,}33 * 2{,}2 = 1{,}09;\ C_{Zn\ actual} = 1{,}02$$

$$C_{Zn\ chernozems\ typical} = 0{,}23 + 2{,}65 * 1{,}2 - 0{,}33 * 4{,}8 = 1{,}8;\ C_{Zn\ actual} = 1{,}75$$

where C_{Zn} – predicted (calculated) content of zinc in the soil, mg/kg; x – calorific value of soil humus, MJ/kg; y – total content of soil humus, %.

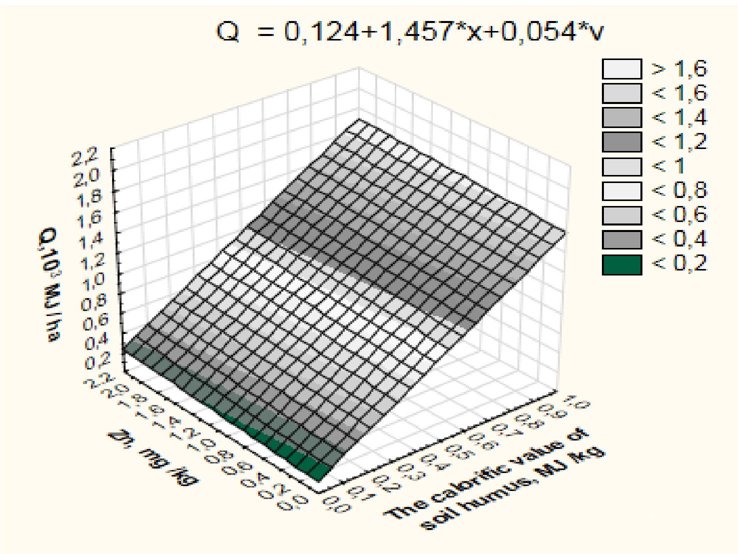

Fig. 1. **The visualized model of established relationships between energy and Zn content in soil**

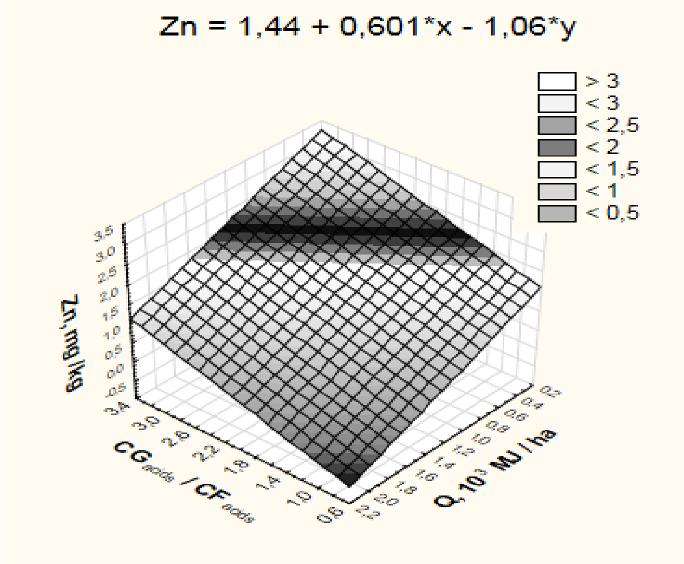

Fig. 2. **The visualized model of established relationships between Zn content in soil, energy and soil humus indices**

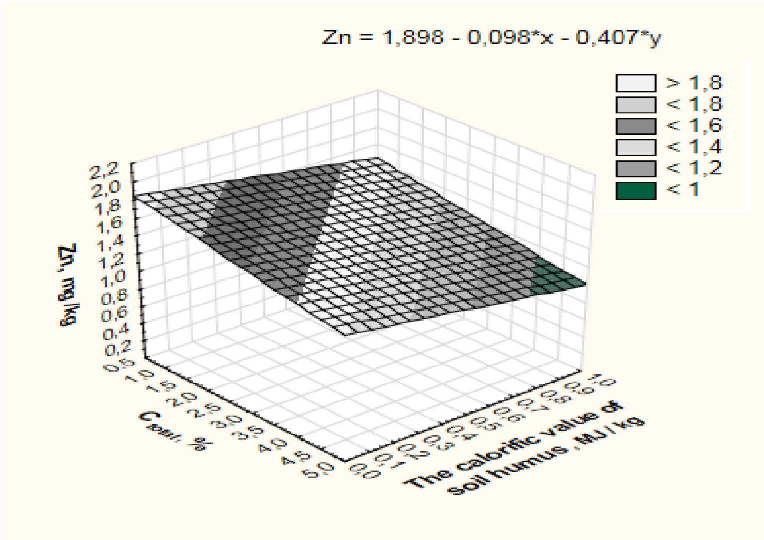

Fig. 3. **The visualized model of established relationships between Zn content in soil, energy and soil humus indices**

Using these formulas on other types of soils, including the influence of technological load and technogenic pollution, has confirmed the universality of the resulting equations. The resulting formulas of calculations of the chemical elements forecast values are universal for different soil types, which are combined in a series on the basis of the predominance of the soil prosses, such as podzolic or chernozems soil series.

Determination of the TE/HM forecasted content, for example, Zn in the soils was estimated based on the using only $C_{G\ acids}$ / $C_{F\ acids}$ ratio, according to the prescribed us a formula for soils, for example, podzolic series C_{Zn} = 1,59 + 0,14 $C_{G\ acids}$ / $C_{F\ acids}$ gave the following values, which when compared with the actual values have a large error:

$Zn_{dark\text{-}grey\ soil}$ = 1,59 + 0,058 * 2,04 = 1,71; Zn_{actual} = 1,06

$Zn_{gray\ podzolic\ soil}$ = 1,59 + 0,058 * 0,9 = 1,64; Zn_{actual} = 1,92

where C_{Zn} – predicted (calculated) zinc content in the soil, mg/kg.

According to the laws of mathematics and the rules of regression analysis, which is automatically obtained regression equations with given the measurements, in particular mg/kg (with specified initial values MJ/ha, MJ/kg and %) but follow the procedure of standardization of variables.

In manual mode this requires the introduction of an additional unit of the multiplier factor of the intensity of energy processes in the soil ($F1 = C_{Zn}/x$), and factor of energy saturation in the analyzed soil layer ($F2 = C_{Zn}/z$) using their physical units. In addition, free terms of the equations according to the rules of regression analysis also have the same units of measurement as the indicator that determines. Regression equations, in particular equations 1–4, take the format of:

1. $C_{Zn} = 2{,}92 + 3{,}72 * x * F_1 - 1{,}59 * y / 100$

$$C_{Zn}\,\frac{mg}{kg} = 2{,}92\,\frac{mg}{kg} + 3{,}72\,\frac{MJ}{kg} * F_1 - 1{,}59\,\frac{mg}{kg} * \% / 100$$

As the result of substitution of all the necessary rules on these units get unit

$$C_{Zn} = \frac{mg}{kg} + \frac{MJ}{kg} * \frac{mg}{MJ} - \frac{mg}{kg} = \frac{mg}{kg}$$

Where F_1 is the correction factor (the factor intensity of soil energy processes).

Factor intensity is defined as follows:

$$F_1 = \frac{C_{Zn}}{x} = \frac{mg}{kg} / \frac{MJ}{kg} = \frac{mg}{MJ}$$

The numerical F_1 values are unknown yet and require more in-depth detailed investigations. Probably that it is some constant values for each type and subtype of soils.

100 – conversion percentage.

Similarly, the action of receiving C_{Zn} units are to be performed in the following regression equations.

2. $C_{Zn} = 2{,}63 - 8{,}95 * z * F_2 + 3{,}55 * y / 100$

$$C_{Zn}\,\frac{mg}{kg} = 2{,}63\,\frac{mg}{kg} - 8{,}95 * \frac{MJ}{ha}\,F_2 + 3{,}55\,\frac{mg}{kg}\,\% / 100$$

$$C_{Zn} = \frac{mg}{kg} - MJ\ /10^7 kg * \frac{mg}{MJ} * 10^7 + \frac{mg}{kg} = \frac{mg}{kg}$$

The mass (m) of 1 ha soil and soil layer of 1 m = ρv = ρsh

$m = g/cm^3 * 10^4 * \cdot m^2 \cdot * m = kg * 10^4\ m^3 / 1 \cdot 10^{-3} m^3 = 10^7\ kg$

Where F_2 is the correction factor (factor of energy saturation in the analyzed soil layer), $\frac{mg}{MJ} * 10^7$

The numerical F_2 values are unknown yet and require more in-depth detailed investigations. Probably that it is some constant values for each type and subtype of soils.

100 – conversion percentage.

The factor of energy saturation is defined as follows:

$$F_2 = \frac{C_{Zn}}{z} = \frac{mg}{kg}\ 10^7\ kg / MJ = \frac{mg}{MJ}\ 10^7$$

3. $C_{Zn} = 2{,}10 - 1{,}33 * z * F_2 + 0{,}42 * j$

$$C_{Zn}\,\frac{mg}{kg} = 2{,}10\,\frac{mg}{kg} - 1{,}33 * \frac{MJ}{ha}\,F_2 + 0{,}42\,\frac{mg}{kg}$$

$$C_{Zn} = \frac{mg}{kg} - MJ / 10^7\ kg * \frac{mg}{MJ} * 10^7 + \frac{mg}{kg} = \frac{mg}{kg}$$

Where F_2 is the correction factor (factor of energy saturation in the analyzed soil layer), $\frac{mg}{MJ} * 10^7$

100 – conversion percentage.

The factor of energy saturation is defined as follows:

$$F_2 = \frac{C_{Zn}}{z} = \frac{mg}{kg}\ 10^7\ kg / MJ = \frac{mg}{MJ}\ 10^7$$

4. $C_{Zn} = 1{,}43 - 2{,}37 * x * F_1 + 0{,}81 * j$

$$C_{Zn}\ \frac{mg}{kg} = 1{,}43\ \frac{mg}{kg} - 2{,}37\ \frac{MJ}{kg} * F_1 + 0{,}81\ \frac{mg}{kg}$$

$$C_{Zn} = \frac{mg}{kg} - \frac{MJ}{kg} * \frac{mg}{MJ} + \frac{mg}{kg} = \frac{mg}{kg}$$

Where F_1 is the correction factor (the factor intensity of soil energy processes), $\frac{mg}{MJ}$.

Similarly, the actions of receiving C_{Zn} units are to be performed in the 5–8 following regression equations.

Spreading the algorithm method for other soil types, as well conduct further calculations to obtain relevant equations of dependencies (patterns), which determine the predicted value of the TE /HM content in soils of different genesis. Thus, on the basis of established regular linear relations, we have proved the conformity of the level of energy intensity of soil humus status, levels of TE / HM, and hence the feasibility of their using due to the background conditions and influence of technological and technogenic loads (Table 1–3).

During the calculation of the trace element soil status were taken into account the following diagnostic combination of quantitative indicators of energy soil formation and functional-environmental diagnosis of the soil genetic status – C_{total} and $C_{G\ acids}$ / $C_{F\ acids}$; C_{total} and calorific value of soil humus; C_{total} and Q; $C_{G\ acids}$ / $C_{F\ acids}$ and Q; $C_{G\ acids}$ / $C_{F\ acids}$ and the calorific value of soil humus. The obtained results listed in the table (Table 2–3, fragment). Thus, the design content, such as, Zn in soils podzolic series by using of matching pairs C_{total} and calorific value of soil humus varies from 1,0 to 1,8 mg/kg due to the background conditions for 1,25 mg/kg of soil due to technological loads. The content of Zn in chernozems soils due to background conditions was 1,75 mg/kg; due to the HM technogenic pollution – 55,4 mg/kg of soil (Table 2–3).

Using each selectively chosen pair of diagnostic indicators of soils environmental and energy status confirmed the possibility of obtaining accurate forecast data of elements soils status (the lack of ME, the excess of HM). At the same time provides the ability to predict soils energy and humus status by solving the inverse problem of calculating the quantitative parameters of one indicator on the basised on the correlation related to other known (Fig. 1, 2, 3). For example, the calorific value of humus and /or energy reserves of the soil particular type on the basis of the known index of the TE / HM content and /or soil organic matter energy intensity for effective environmental regulation and management of soil quality. Diagnostic efficiency of indicating the direction of the humification-mineralization processes in soil systems by humus and energy status indices confirmed by appropriate mathematical models (equations) (Fig. 1, 2, 3).

The selective choice of the proposed diagnostic complex combinations of humus and energy state indicators, only those that are available, can reduce the cost of resources for the prediction of the elemental status of soil, environmental and energy state and ration of their quality. This gives the opportunity to control soil quality and productivity due to the impact on the processes of mineralization-humification, elemental status and reserves of soil organic matter that determine the quality of their humus status and dynamic equilibrium, and, accordingly, the soils ability of different genesis to restore energy resources due to the accumulation, energy distribution and maintaining a certain level of intensity.

The gradation of soil quality carried out by the classification method of grouping data on the basis of soil energy intensity by qualitatively comparable classes with equal intervals and a preliminary definition of the amount (N) and taking into account the volume sample data (V) according to the well known equation:

$$N = 2 \ln V \qquad (10)$$

The value of the interval (A), as a sign of the classification determined by dividing the magnitude of variation in number of intervals for the well-known formula:

$$A = (Xmax - Xmin) / N \qquad (11)$$

where Xmax and Xmin – maximum and minimum values of the trait classification.

Table 2

Estimated and actual parameters of soils elemental status for various types of background conditions

TE/HM	Predicted / actual * content of elements mobile forms in soil, mg/kg									
	Soils of the podzolic series		*Soils of the chernozems series*			*Soils of the podzolic series*		*Soils of the chernozems series*		
	Sod-podzolic	Dark-grey	Chernozem typical	Chernozem ordinary	Chernozem southern	Sod-podzolic	Dark-grey	Chernozem typical	Chernozem ordinary	Chernozem southern
	Using ratio of $C_{G\ acids}$ / $C_{F\ acids}$ (according to the prototype method)					*Using C_{total} indicator and the calorific value of humus in the soil*				
	In the absence of loads (background conditions)									
Zn	1,5/1,7*	1,71/1,06*	1,3/1,8*	1,3/0,15*	1,4/1,02*	1,8/1,7*	1,1/1,06*	1,75/1,80*	0,14/0,15*	1,09/1,02*
Cd	0,17/0,13*	0,17/0,15*	0,2/0,13*	0,2/0,11*	0,16/0,2*	0,13/0,13*	0,15/0,15*	0,12/0,13*	0,10/0,11*	0,19/0,2*
Mn	24,2/20,97*	20,2/17,6*	20,1/12,54*	21,65/18,18*	22,9/30,72*	20,97/20,97*	17,58/17,6*	12,54/12,54*	18,18/18,18*	30,7/30,72*

Table 3

Estimated and actual parameters of soils elemental status for various types of the impact of anthropogenic loads

TE/HM	Predicted / actual * content of elements mobile forms in soil, mg/kg			
	Soils of the podzolic series	*Soils of the chernozems series*	*Soils of the podzolic series*	*Soils of the chernozems series*
	Dark-grey	Chernozem ordinary	Dark-grey	Chernozem ordinary
	Using ratio of $C_{G\ acids}$ / $C_{F\ acids}$ (according to the prototype method)		Using C_{total} indicator and the calorific value of humus in the soil	
	Due to the the influence of different fertilizer systems (technological load)	Due to the the influence of HM pollution (technogenic load)	Due to the the influence of different fertilizer systems (technological load)	Due to the the influence of HM pollution (technogenic load)
Zn	1,5/1,2*	62/54,3*	1,25/1,2*	55,4/54,3*
Cd	0,5/0,07*	7,5/5,2*	0,07/0,07*	5,5/5,2*
Mn	57,01/45,66*	41,1/22,2*	45,42/45,66*	22,4/22,2*

*Note. *In Table 2 and 3 the actual content of TE /HM mobile forms in the soil, mg/kg.*

In our case N = 2 ln 8 = 4,1; A = 0,913 - 0,106/4 = 0,20. Given the magnitude of variation of the interval range values allocated to a comparison classes (Table 4). Thus, the 1st class of quality combines soils with higher energy reserves and are more resistant to external influences and characterized by higher productivity; 4th class quality combines soils with minimal energy intensity.

The method allows according to the level of the soils energy state normalized their quality, as well as to adjust the content of the TE/HM, conducting the control measures of the soil organic matter reservs due to the different systems of agriculture, the impact of technological load and technogenic pollution on the soil and to maintain and preserve the indicators of its energy intensity as criteria for determining its quality. There is a possibility to controll influence on the processes that leading to decrease of free energy in the soil and increase entropy and energy that is associated with humus, which improves soil productivity.

Changes of integral indicators of the soil ecological and energy status allows assessment of its ecological functions, agricultural technologies, fertilizers systems and agriculture in agro- and ecosystems, which gives the opportunity to identify promising areas of soil resources better applying, provides the elimination of negative impacts on environmental and energy state of the soil using of less energy-intensive activities to restore soil fertility for displays of degradation processes and reducing the costs of anthropogenic energy on overcoming them.

Table 4

Ranking of the soils productive function in terms of intensity as criteria of their ecological and energy state

Estimation of different genesis soils in quality			
Climatic zone. Type of soil	The soil quality class	The soil energy intensity	Productive function (fertility)
Polesie. Sod-podzolic Forest-steppe. Light-grey	4	<0,11	low
Forest-steppe. Grey podzolized Forest-steppe. Dark-grey Steppe. Dark chestnut	3	0,31 – 0,51	average
Steppe. Chernozem southern	2	0,51 – 0,71	high
Steppe. Chernozem Ordinary Forest-steppe. Chernozem typical	1	>0,71	very high

Scientific elaboration is secured by protection document (Pat. of Ukraine for invention, № 113828 UA, 2017).

CONCLUSIONS

1. Distinctive features and advantages of the elaborated method in comparison with known methods and approaches are as follows:

a) the elevated predictability of elemental, humus, energy status and ecological state of a certain soil type in general for the assessment of soils environmental and energy state, levels of their fertility in the application of different fertilizing systems, risk and the availability of HM pollution, to prevent the degradation of soil organic matter and reducing risks of HM technogenic pollution influences of HM technogenic pollution risks;

b) the express receipt and improve the accuracy of the predicted critical TE/HM concentration in the soil and a simultaneous minimization costs of resources;

c) the versatility of the method due to suitability of the established dependencies of the proposed method for all soil types, climatic zones and contaminants;

d) the ensuring the effective using of diagnostic pairs of soil properties indicators due to the humus substances interaction and energy expenditure on the humification-mineralization processes in soils of different types on the basis of the soils elemental status prediction;

e) the possibility of applying this algorithm for the assessment and rating quality of different genesis soils use any of soils ecological functions and identifying the optimal energy costs for their reproduction;

f) the updating further elaborations of new criteria and indicators for assessment and rationing of the soils quality status with regard to elemental (micro – and macronutrient status, humus and energy state including technological load and technogenic pollution, to stimulate further researches on energetics of soil formation and solving of practical tasks of different genesis soils functions conservation and restoration.

2. The scientific elaboration should be used in environmental regulation of the TE content and the regulation of lods (technogenic, technological) on the soil system, in agroecology in issues of organic farming, bioenergy and energy of soil formation; diagnosis, estimation, prediction of humus quality and the TE status and the danger of excessive HM accumulation in the soil for indicators of the energy state; for the effective environmental management of soils as in natural conditions and the impact of various anthropogenic loads, taking into account ecological functions of soils; in research practice - for system research of the biosphere natural components, the assessment of carbon sequestration in soils and the assessment and regulation of their quality.

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