Monitoring of Arable Land Fertility Based on Agrochemical Analysis and Dynamics of Changes in Soil Organic Matter Reserves

E V Dolobeshkin¹, A D Gumbarov¹ and M A Bandurin¹

¹Kuban State Agrarian University named after I T Trubilin, 13, Kalinina St., Krasnodar, 350044, Russia

E-mail: dev.kubsau@mail.ru

Abstract. The article considers the problems of food security on the example of assessing the initial state of arable land fertility. Agrochemical soil analysis makes it possible to determine the direction of a complex of reclamation measures that can significantly increase soil fertility. The need for this is defined due to the development of degradation processes in the soil, as a result of which the reserves of soil humus and basic nutrients necessary for the productive development of plants have sharply decreased. The authors of the article proposed the evaluation of the initial fertility of arable land on the main agrochemical parameters (humus G, nitrogen N, phosphorus P, potassium K and hydrolytic acidity Ng). Based on the data of agrochemical soil laboratory in the farm "Memory of Lenin" in Krasnodar Territory, an initial average agrochemical state of arable land, which was the initial and maximum index of fertility (S(G), S(NPK), S(Ng) and the composite index of the soil - S). The complex of reclamation measures should be aimed at: increasing the reserves of humus in the soil, as a result of additional input of soil biomass; increasing the doses of mineral fertilizers, bringing the ratio of mineral nutrition elements to the optimal. To determine the trend of changes in the state of arable land, it is necessary to forecast it.

1. Introduction
At the present stage of application of digital technologies in agriculture, soil fertility mainly depends on the amount, composition of humus and basic soil nutrients (NPK). On lands that are in agricultural circulation, due to the reduction of biomass reserves in the soil, a shortage of humus is gradually formed. A balance in the content of humus in the soil can be achieved when its consumption by cultivated plants is completely covered by the introduction of organic and mineral fertilizers, crops of perennial legumes, with a greater share in arable lands, and the introduction of by-products back into the field (plant stems, straw, greens) [1].

The demand of agricultural crops in nitrogen, at optimal doses of nitrogen-containing mineral fertilizers, is met by 50% due to soil organic matter (humus) and 50% due to fertilizers applied to the soil [2]. Many authors used to calculate the humus balance [3, 4, 5, 6, 7, 8]. Their calculation was based on data from a short study period. Of particular relevance is the ability to track the dynamics of changes in the balance of humus of arable land, as a result of changing values of crop yields and the structure of arable land over a long period of time.

The dynamics of the humus balance under changing conditions of the structure of arable land and
crop yields is studied and analyzed. The dependence of the humus balance on the yield for cereals and perennial legumes is described.

2. Materials and methods
The dynamics of changes in biomass reserves in the soil on non-irrigated arable land of the Timashevsky district of Krasnodar Territory is considered. Soils are zonal chernozems, meadow-chernozem and meadow with vegetation typical for this climatic zone [9]. The main changes in the state of the natural and technogenic complex under consideration are related to the development of agricultural production. It was accompanied by the replacement of natural biocenoses with agrocenoses and changes in the main environmental factors (hydrothermal regime and total biomass reserves) that determine the properties, soil fertility and environmental sustainability. The calculations used historical data on the development of the territory, the structure of acreage and crop yields from 1800 to 2020 [10, 11] (Figure 1).

![Figure 1. Dynamics of replacement of natural and agricultural land shares in Timashevsky district of Krasnodar Territory.](image-url)

The method of calculating the humus balance is based on the record of the nitrogen content in humus. The basis of determining the dynamics of humus is based on guidelines of calculating soil humus, with a number of clarifications included in the calculation technology of the Russian Scientific Research Institute of Land Projects [12]. The solution to this issue is based on the "Mathematical model of soil fertility dynamics", which takes into account all the above recommendations and methods of calculation [13, 14].

When growing crops the by-products (stems, haulm) are transferred along with yield in the process of harvesting, in this case, the soil receives waste only in the form of the plants (stubble, fallen dry leaves) and root residues, which greatly reduces the stock of biomass, and hence the total accumulation of humus, which together with the main nutrients (NPK) are the main components of soil fertility.

Nitrogen removal from the crop and by-products is defined as the difference between the nitrogen content of the crop and by-products and fixed nitrogen from the atmosphere multiplied by the correction coefficients of nitrogen removal related to the cultivation technology and the mechanical soil composition.

A comparative analysis was made for two agricultural crops of arable land - winter wheat, alfalfa for hay, and the collective farm "Memory of Lenin" of Timashevsky district of Krasnodar Territory. In the agricultural production of the collective farm, more than 86% (7618 ha) of the farm's land is used, of which 91.3% (6953 ha) is occupied by arable land [15]. The main section № 1 is located in the Northern part of Timashevsky district, and section № 2 is located south of Timashevsk. It is significantly removed from the central estate (25 km). In agricultural production, more than 86% (7618 ha) of the farm's land is used, of which 91.3% (6953 ha) is occupied by arable land. The structure of arable land consists of 4 rainfed crop rotations and 3 irrigated (2-feed, 1-vegetable) crop
rotations. An explication of agricultural crops included in the crop rotation of the arable land of the collective farm "Memory of Lenin" is given. The analysis of the initial status of each agrochemical crop rotation of arable land is made on the average indicators (horizon 100 cm) based on data from soil surveys, field rotations held by the Krasnodar regional agrochemical laboratory in 1976 in the collective farm "Memory of Lenin" [16, 17].

The analysis of the initial state of arable land from the maximum possible one on the integral indicators of the soil index clearly identifies two components of fertility; humus reserves (SG) and reserves of basic elements of mineral nutrition (SNPK). There is a pronounced deficit (negative balance) in the difference between the maximum and initial state of the corresponding indicators; Δ SG = -3.44 units, Δ SNPK = -3.52 units. At the same time, the fertility indicators of SG and SNPK are only 46.3% and 58.6%, respectively, of the maximum.

Figure 2 shows the joint dynamics of changes in the yield and share of these crops in arable land, according to the data of the Federal State Statistics Service of Krasnodar Territory and the Republic of Adygea from 1962 to 2019 [18, 19].

![Figure 2](image_url)

**Figure 2.** Yield and share of crops in arable land: a crop yield, C/ha; b share of crops in the arable land.

According to the method of calculating the humus balance of winter wheat and alfalfa for hay described above, the direct linear dependencies were established with the description of the equation of the straight line with angular coefficients, between the yield and the humus balance of the corresponding crops (Figure 3).
It should be noted that the initial indicator of hydrolytic acidity of Snd is almost identical to the maximum; Δ SNg = -0.01 units – which is 99.8% of the maximum and indicates that there is no deficit. The generalized integrator of arable land fertility S is 65.2% of the maximum with a balance of Δ S = -6.96 units. Reserves of humus and soil nitrogen are at the level of 85.5%, K2O-90.5%, phosphorus reserves-the smallest of the main soil nutrients are P2O5-26%.

In the same way, a methodical calculation was made [20] of the humus balance, taking into account changes in the share structure under the corresponding arable crops (Figure 4).

**Figure 3.** Dependence of humus on yield: *a* alfalfa for hay; *b* winter wheat.

**Figure 4.** Humus balance taking into account the share of agricultural crops in arable land.

The analysis of the obtained data, when applying the method of calculating the humus balance, first
of all indicates a linear dependence of the change in the humus balance on the changing values of the crop yield [21]. Thus, for perennial legumes (alfalfa for hay), when the yield increases, there is a linear increase in the humus (Gg) alfalfa entering the soil with a straight slope coefficient (+0.63). Mineralized humus (Gm) alfalfa also has a straight slope coefficient (+0.093), which in turn indicates a positive increase in the balance of humus (ΔG) alfalfa with a straight slope coefficient (+0.53). A different picture is observed in cereals (winter wheat) [22]: (Gg) wheat – (+0.16); (Gm) wheat – (+0.46). The humus balance of winter wheat, due to less humification and greater mineralization of humus, has a negative increase with increasing yield, (ΔG) wheat - the slope coefficient of the straight line (-0.295) [23].

The time of stabilization of biomass reserves depends on the humification coefficient: the higher the humification coefficient, the faster the reserves are stabilized. Figure 5 shows that even with a small humification coefficient, the relaxation time is no more than 50 years [24].

![Figure 5. Graphs of the function of annual grasses on hay at different values yields: a stabilization of biomass reserves in the soil under annual grasses for hay, depending on the yield; b time of stabilization of relative biomass reserves in the soil, depending on the coefficient of plant humification.](image)

Despite the fact that in recent years there has been a tendency to increase the crop yield, the total biomass reserves remain at a low level. At the same time, the overall decrease in soil biomass reserves, relative to the indicators that occurred at the beginning of the 19th century, was about 220 C/ha. The determining factors of this can be the decrease in the species diversity of vegetation and the annual export of crop and by-products from the fields. The supply of humus to the soil directly depends on the biomass reserves in the soil, respectively, a decrease in the total biomass reserves leads to a decrease in the supply of humus to the soil, thereby reducing its fertility [25]. It is necessary to change the system of agriculture, increasing the percentage of perennial grasses in the crop rotation, the use of organic fertilizers, siderates and the return of crushed by-products to the fields.
3. Conclusion
The process of accumulation of arable humus reserves, in addition to applying doses of organic (litter manure) and mineral fertilizers, is affected by the positive dynamics of the humus balance under arable crops. The main factors affecting both the positive and negative balance of arable humus are:
- share of agricultural crops in arable land;
- crop productivity of arable land.
Moreover, the primary influence is directly influenced by the weight share of the crop in the structure of arable land. Thus, for humus-forming crops, the deficit balance of arable humus can be covered by increasing the share of these crops in the structure of arable land, and for humus-consuming crops, respectively, reducing the share of crops in the structure of arable land.
Crop yield has approximately the same effect as the weight value, only in smaller values on the humus balance. For humus-forming crops, the trend to increase the yield leads to an increase in the values of the humus balance under these crops, respectively, for humus-consuming crops, an increase in the yield leads to an even greater deficit of the humus balance under these crops.

4. References
[1] Kuznetsov E V, Safronova T I, Sokolova I V, Khadzhidi A E, Gumbarov A D 2017 Development of a land resources protection model J. of Environmental Management and Tourism 8.1(17) 78-83
[2] Kireicheva L V, Zakharova O A 2002 The effect of cyclic irrigation with wastewater on the properties of gray forest soils Eurasian Soil Science 35(9) 990-995
[3] Trubilin E I, Borisova S I, Konovalov V I, Chebotarev M I, Gumbarov A D 2020 Experimental studies of parameters of pneumatic slot sprayer Int. J. of Emerging Trends in Engineering Research 8(1) 170-176
[4] Pukhovski A V 2002 X-ray fluorescence analysis in the russian state agrochemical service: an overview X-Ray Spectrometry 31(3) 225-234
[5] Yurchenko I F 2017 Automatization of water distribution control for irrigation Int. J. of Advanced and Applied Sciences 4(2) 72-77
[6] Abdrasakov F K, Orlova S S, Pankova T A, Mirkina E N, Mikheeva O V 2018 Risk assessment and the prediction of breakthrough wave during a dam accident J. of Int. Research 8(1) 154-161
[7] Kuznetsov E V, Khadzhidi A E, Poltorak Y A, Kuznetsova M 2019 Operator model to control process of obtaining vermicompost Eurasian J. of BioSciences 13(1) 315-321
[8] Olgarenko V I, Olgarenko G V, Olgarenko I V 2018 A method of integral efficiency evaluation of water use on irrigation systems Int. Multidisciplinary Sci. GeoConf. SGEM 18(3.1) 3–9
[9] Ovchinnikov A S, Bocharnikov V S, Skorobogatchenko D A, Borisenko I B, Chernyavsky A N, Abezin V G, Ryadnov A I, Shaprov M N, Kuznetsov N G, Nekhoroshev D A, Sedov A V, Grigorov S M, Fomin S D, Olgarenko V I 2018 The optimum geometrical form modeling of the "striegel" type harrow ARPJ. of Engineering and Applied Sciences 13(23) 9138-9144
[10] Kuznetsov E V, Khadzhidi A E, Kilidi K I, Kurtenzirov A N 2018 Management of agro-resource potential for agricultural landscape stability increase Plant Archives 18(2) 2151-2158
[11] Bandurin M A, Yurchenko I F, Bandurina I P 2019 Computer technology to assess the capacity reserve of the irrigation facilities of the agro-industrial complex Int. Multi-Conf. on Industrial Engineering and Modern Technologies (FarEastCon) 1-5 doi: 10.1109/FarEastCon.2019.8933970
[12] Abdrasakov F K, Pankova T A, Zatinatsky S V, Orlova S S, Trushin Yu E 2017 Increasing efficiency of water resources use in forage crops irrigation Int. J. of Advanced Biotechnology and Research 8 283-293
[13] Bandurin M A, Yurchenko I F, Volosukhin V A 2018 Remote monitoring of reliability for water conveyance hydraulic structures Materials Science Forum 931 209-213
[14] Yurchenko I F 2018 Information support system designed for technical operation planning of reclaimative facilities J. of Theoretical and Applied Information Technology 96(5) 1253-1265
[15] Kireicheva L V, Khokhlova O B 2000 Elemental composition of different fractions from the sapropel organic matter Eurasian Soil Science 33(9) 947-949
[16] Priporov I E, Kurasov V S, Chebotarev M I, Gumbarov A D, Kuznetsov EV 2020 Capacity of air-and-screen grain cleaner as component of production line of sunflower meal Int. J. of Emerging Trends in Engineering Research 8(1) 157-163
[17] Bandurin M A, Volosukhin V A, Vanzha V V, Mikheev A V, Volosukhin Y V 2018 Finite-element simulation of possible natural disasters on landfill dams with changes in climate and seismic conditions taken into account J. of Physics: Conference Series 1015(3) 032011
[18] Degtyarev G V, Belokur K A, Sokolova I V 2018 Modeling of the building by numerical methods at assessment of the technical condition of structures Materials Science Forum 931 141-147
[19] Bandurin M A, Yurchenko I F, Volosukhin V A, Vanzha V V, Volosukhin Ya V 2018 Ecological and economic efficiency of diagnostics of technical condition of water supply facilities of irrigation systems J. Ecology and Industry of Russia 22(7) 66-71
[20] Gaydzhurov P P, Kravchenko G M, Savelieva N A 2014 Finite element modeling of elastic plastic bending of steel beams with use of rod end elements Construction mechanics and design of structures 2 17-22
[21] Chesnokov B P, Abdrazakov F K, Naumova O V, Krivoschapov D S, Strelnikov V A 2017 The use of ionizing radiation for the tungsten preparation J. of Industrial PollutionControl 1-12
[22] Chesnokov B P, Naumova O V, Strelnikov V A, Abdrazakov F K, Tronin B A 2016 Polyethylene production from granules using high voltage Int. J. of Applied Engineering Research 11 2140-2144
[23] Degtyarev V G, Kozhenko N V 2019 Consolidation processes in clay soils, taking into account the multistory building construction staging IOP Conf. Series: Materials Science and Engineering 698(2) 022016
[24] Abdrazakov F K, Ryzhko N F, Ryzhko S N, Horin S A, Botov S V 2018 Electricity consumption decrease at pump stations during watering by multi-support sprinkling units J. of Fundamental and Applied Sciences 10 1464-1481
[25] Fen N, Kozlov D B, Rumyantsev I S 2016 Hydraulic studies of stepped spillways of various design Power Technology and Engineering 49(5) 337-344