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# METHODS OF STUDYING SOIL INDICATORS OF AGROECOSYSTEMS

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## ABSTRACT

Soil is a key component of the ecosystem, providing a number of useful services to humans. Many driving factors threaten the sustainable functioning of soils, and therefore the entire agroecosystem. This article discusses soil indicators for studying the state of agroecosystems. A list of methods and the course of work are given in detail. Soil research allows for rational use of the sowing area, makes it possible to observe changes in the composition and properties of the soil, obtain data on the amount of nutrients available to the plant and its fertility, and helps to choose suitable seeds and fertilizers. The results of the analysis and recommendations of a specialist allow you to determine the best time for sowing and get a larger harvest.

**Keywords:** soil, soil indicators, research methods, agroecosystems, agriculture, fertility.

## INTRODUCTION

Soil is an important part of the biosphere, the upper fertile layer of the earth, which is formed as a result of the interaction of living and nonliving nature. The soil consists of various components: sand, clay, humus, air, water. Also, an integral part of the soil are living organisms: animals, plants (their roots), fungi, bacteria, lichens (Aparin, 2012; Belitsyna et al., 1988; Valkov et al., 2004b).

Situated on the boundary of contact and interaction of the lithosphere, atmosphere and hydrosphere, the soil plays a specific role in the complex system of planetary shells, forming a special geosphere – the pedosphere, or the soil cover of the earth. In this case, the role of the soil is reduced to performing several global functions (Aparin, 2012; Belitsyna et al., 1988; Odabashyan et al., 2018; Valkov et al., 2004b).

The global functions of the soil are very multifaceted. The first and main of them is to ensure the existence of life on Earth. It is from the soil that plants, and through them animals and humans, receive mineral nutrients and water to create their biomass. The soil accumulates the biophilic elements necessary for organisms in forms of chemical compounds available to them. Land plants take root in the soil, a huge mass of soil-dwelling animals live in it, it is densely populated by microorganisms (Aparin, 2012; Belitsyna et al., 1988; Prokopchuk et al., 2018; State Standard of the USSR, 1985a; Valkov et al., 2004b).

The second most important global function of the soil is to ensure the constant interaction of the large geological and small biological cycles of substances on the earth's surface. These elements are captured from the soil by plants and through a series of intermediate trophic cycles (plants - animals - microorganisms) return back to the soil, which constitutes the small biological cycle of substances.

The third global function of soil is to regulate the chemical composition of the atmosphere and hydrosphere. Soil "respiration" together with photosynthesis and the respiration of living organisms plays a decisive role in the creation and maintenance of the composition of the surface layer of atmospheric air, and through it the atmosphere as a whole (Prokopchuk et al., 2018; State Standard of the USSR, 1985a; Valkov et al., 2004b).

The fourth global function of soil is the regulation of biosphere processes, in particular the density of life on Earth, through the dynamic reproduction of soil fertility, in which the dialectic of nature is again clearly manifested, since the soil has properties that ensure the life of plants, and factors that limit it. The fifth global function of soil is the accumulation of active organic matter and the chemical energy associated with it on the earth's surface (Aparin, 2012; Belitsyna et al., 1988).

The main property of soil for humans is fertility. This is the ability to supply plants with nutrients, water and air for their full growth and development. For humans, soil is a source of agricultural products (Odabashyan et al., 2017b; State Standard of the USSR, 1984).

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Sustainable agriculture is an approach to farming that aims to meet current needs for food, crops, and other agricultural products while ensuring the long-term health and productivity of soil resources, minimizing negative impacts on the environment, and supporting the well-being of farming communities (Korotenko and Togusakov, 2023; Mirzagitova et al., 2023). Sustainable agriculture prioritizes maintaining and improving soil quality (Chebyshev et al., 2024; Zhyrgalova et al., 2024).

This includes practices such as soil testing, crop rotation, cover crops, and reducing tillage to improve fertility (Almanova et al., 2023). Nutrient management encourages farmers to apply fertilizers more efficiently, reducing overuse, and minimizing nutrient losses that can harm the environment (Odabashyan et al., 2017a).

## MATERIALS AND METHODS

World and domestic experience shows that high and sustainable productivity of agriculture is possible only with a comprehensive consideration of all agrochemical and environmental factors (Rednikova, 2023) necessary for normal growth and development of plants, formation of crop yield and its quality, prevention of land degradation (acidification, salinization, compaction, erosion, deflation, depletion of organic matter reserves and nutrients available to plants, pollution with harmful substances, etc.) (Sheudzhen et al., 2007; Spirina and Solovieva, 2014;

State Standard of the USSR, 1984; Valkov and Zharkova, 2008; Valkov et al., 2012). By satisfying the needs of agricultural crops, taking into account their biological characteristics, for nutrients (N, P, K, Ca, Mg, S, microelements) (table 1-3), water, air, heat and creating optimal reactions of the soil environment for plants, phytosanitary and other conditions and by cultivating highly productive varieties adapted to local conditions with a high level of agricultural technology, it is possible to increase yields by 2 times or more against current levels.

Table 1. Agrochemical indicators and research methods.

| No. | Soil indicators | Research method |
|---|---|---|
| 1 | Determination of soil temperature | Pyrometer DT-810 "SEM". The range of measured temperatures is from -50 to +800°C with an error of 1.5°C |
| 2 | Determination of soil moisture | A moisture meter with a Thetaprobe sensor that determines the volumetric moisture content of the soil |
| 3 | Determination of the reaction of the environment (pH) | Potentiometric method |
| 4 | Determination of electrical conductivity | Conductometric method |
| 5 | Determination of nitrates | Ionometric method |
| 6 | Determination of organic matter content | According to I.V. Tyurin, modified by V.V. Nikitin |
| 7 | Determination of granulometric composition | By sieve method |
| 8 | Determination of hydrolytic acidity | By the Kappen method in modification Central information scientific and analytical association |

Table 2. Biochemical parameters and research methods.

| No. | Soil indicators | Research method |
|---|---|---|
| 1 | Catalase activity | By A.Sh. Galstyan (1956) |
| 2 | Dehydrogenase activity | By A.Sh. Galstyan (1956) |
| 3 | Invertase activity | Colorimetric method with Felling's reagent |
| 4 | Phosphatase activity | By A.Sh. Galstyan, E.A. Harutyunyan (1966) |
| 5 | Urease activity | By A.Sh. Galstyan (1965) |

Table 3. General soil indicators and methods of their study.

| Indicators | Reagents | Equipment | Regulatory Document |
|---|---|---|---|
| pH of aqueous extract | Distilled water | Mortar, pestle, sieve 1-2 mm, spatula (spoon), laboratory scales, graduated cylinder, containers (flasks) 150 ml, shaker, pH meter | GOST 26423-85 |
| pH of salt extract | KCl, distilled water | Mortar, pestle, sieve 1-2 mm, spatula (spoon), laboratory scales, graduated cylinder, containers (flasks) 150 ml, shaker, pH meter, magnetic stirrer | GOST 26483-85 |
| Organic matter | Distilled water, sulfur-chromium mixture (prepared by dissolving 23.2 g K2Cr2O7 in 400 ml water, then carefully adding 2 l of concentrated H2SO4 with a density of 1.84 g/cm$^3$) | Paper, pestle, tweezers, 1 mm sieve, scales, 50 ml heat-resistant glass test tubes, 25 ml cylinder, 30 cm glass rod, water bath, test tubes, 30 cm long glass rods, rubber bulb, glass tube, 100 ml conical flasks, funnels, spectrophotometer (1, 2, 4 cm cuvettes) | GOST 26213-91 According to Tyurin's method in modification of Central information scientific and analytical association |
| Active carbon | KMnO4, distilled water, CaCl2, HCl or KOH | Sieve 1-2 mm, flasks 50 ml, test tubes 20 ml spectrophotometer, centrifuge, cuvettes 1, 2, 4 cm | Modified Blair Method |
| Catalase activity | Distilled water, hydrogen peroxide | Rubber hose, burettes, double flasks, rubber stoppers, dispensers, pipettes, stand | Method of A.Sh. Galstyan |
| Dehydrogenase activity | 2,3,5-triphenyltetrazolium chloride - TTX, triphenylformazan - TFF, glucose, toluene or iodonitrotetrazolium chloride (INT), N,N-dimethylformamide, distilled water, a mixture of N,N-dimethylformamide with ethanol | 20 ml test tubes, thermostat, drying oven, ethyl alcohol or acetone, spectrophotometer, centrifuge, desiccator | Method of A.Sh. Galstyan |
| Invertase activity | Distilled water, sucrose, toluene, Rochelle salt | Flasks 50 ml, thermostat, test tubes 20 ml, water bath, | Modified colorimetric method of F.Kh. |

| | | | |
|---|---|---|---|
| | (potassium-sodium tartrate), KOH or NaOH, CuSO4, glucose | spectrophotometer, centrifuge, filters, funnels, cork stoppers | Khaziev |
| Phosphatase activity | Distilled water, toluene, sodium phenolphthalein phosphate, potassium alum, NH4OH, phenolphthalein, ethanol or sodium p-nitrophenyl phosphate, CaCl2, NaOH, sodium p-nitrophenyl phosphate, tris (hydroxymethyl) aminomethane (HOCH2)3CNH2, maleic acid, boric acid, citric acid, HCl, KOH | 50 ml flasks, cork stoppers, dense filter, funnels, photoelectric colorimeter, cylinders, dispensers and pipettes | Modified method of A.Sh. Galstyan and E.A. Harutyunyan or the method of M. Tabatabay and J. Bremner |
| "Breathing" of the soil | NaOH or KOH, HCl or H2SO4, phenolphthalein | Sieve 1-2 mm, gauze bags, 250 ml wide-neck flasks, rubber stoppers, thermostat, burettes for titration | Method of A.Sh. Galstyan |
| Humidity | KCl | Buxa, tweezers, mortar, drying oven, desiccator, stoppers | GOST 28268-89 |
| CHEMICAL PROPERTIES OF SOIL | | | |
| Carbonate and bicarbonate ions in aqueous extract | Distilled water, sulfuric acid | Mortar, pestle, sieve 1-2 mm, spatula/spoon, electronic scales, technological containers (cassettes) 150 ml, graduated cylinder, shaker, filters, dispenser/pipette, conical flasks 100 ml, filters, chemical beaker, phenolphthalein, burettes for titration | GOST 26424-85 |
| Chloride ions | Potassium chromate solution | Mortar, pestle, sieve 1-2 mm, spatula/spoon, electronic scales, technological containers (cassettes) 150 ml, graduated cylinder, shaker, filters, dispenser/pipette, conical flasks 100 ml, filters, chemical beaker, phenolphthalein, burettes for titration | GOST 26425-85 |
| Turbidimetric determination of sulfate ion in aqueous extract | Glycerin, distilled water | Mortar, pestle, sieve 1-2 mm, spatula/spoon, electronic scales, technological containers (cassettes) 150 ml, graduated cylinder, shaker, filters, dispenser/pipette, conical flasks 100 ml, filters, chemical beaker, phenolphthalein, burettes for titration | GOST 26426-85 |
| Determination of sodium and potassium in an aqueous extract | Distilled water | Spoon/spatula, electronic scales, process containers (cassettes) 150 ml, graduated cylinder, shaker, filters conical flask 100 ml, Flame photometer FPA-2-01 | GOST 26427-85 |
| Determination of exchangeable potassium by Maslova's method | Ammonium acetate | Paper and pestle, tweezers, Mortar, 1 mm sieve, electronic scales, 150 ml process containers (cassettes), 50 ml cylinder, shaker, filters, flasks, flame photometer | GOST 26210-91 |
| Mass fraction of water-soluble forms of chloride, sulfate, oxalate, nitrate, fluoride, formate, phosphate, acetate ions | Ammonium acetate | Paper and pestle, tweezers, Mortar, 1 mm sieve, electronic scales, 150 ml process containers (cassettes), 50 ml cylinder, shaker, filters, flasks, flame photometer | GOST P 53381- 2009 Federal environmental regulations 16.1:2:2.3:2.2.69-10 |
| Mass fraction of water-soluble | Ammonium acetate | Paper and pestle, tweezers, Mortar, 1 mm sieve, electronic scales, 150 ml | GOST P 53381- 2009 Federal environmental |

| | | | |
|---|---|---|---|
| forms of cations of ammonium, potassium, sodium, magnesium, calcium in soils and grounds | | process containers (cassettes), 50 ml cylinder, shaker, filters, flasks, flame photometer | regulations 16.1:2:2.2:2.3.74-2012 (M 03-08-2011 |

## RESULTS

The fertility of soils of agroecosystems in the long-term plan also depends on climatic conditions, and for specific years – on weather conditions (Kussainova et al., 2023), phytosanitary, ecological-toxicological and radiological state (Bogolyubov, 2023). The integral indicator of effective soil fertility is the yield of agricultural crops (Suraganov et al., 2024), the productivity of forage lands (Kenenbayev et al., 2024), the quality of plant products in compliance with regulatory environmental requirements. Tables 1-2 show the main agrochemical and biochemical indicators of soil and the methods for determining them. Agrochemical parameters of soil include: organic matter content, %; gross content of nutrients: nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, %; content (mg/kg soil) of mobile (available to plants) forms of: phosphorus, potassium, sulfur, magnesium, calcium, iron, boron, molybdenum, manganese, zinc; pHKCl, exchangeable and hydrolytic acidity, exchangeable aluminum, sum of absorbed bases (mg-eq/kg soil), degree of soil saturation with bases (%); specific electrical conductivity (S/m); pH of aqueous extract; content of ions of carbonate and bicarbonate, chloride, sulfate, (g-ion/l); sodium and potassium, calcium and magnesium (mg-eq/kg); absorption capacity, (mgeq/kg); exchangeable sodium, %; exchangeable magnesium in solonetzic horizon, %; gypsum content mg-eq/kg); $CO^2$ of soil carbonates (for solonetzic, saline and irrigated soils) (Table 3). Biochemical parameters of the soil include: activity of catalase (ml O2/min/g), dehydrogenases (mg 2,3,5-TPP /g/), invertase (mg glucose /1 g of soil for 40 hours), phosphatase (mg/kg P2O5), urease (mg NH4/kg of soil) (Table 2).

## CONCLUSION

- Soil fertility includes not only all types of resources required by a plant during the growing season, but also their availability to plants. The latter depends on the structure of the upper part of the soil profile, the mineralogical composition of the soil, the reserves of moisture available to the plant, agrophysical properties that determine both the water-air and thermal regimes of the soil and the possibilities of spatial growth of root systems, as well as the biological properties of the soil. It is quite obvious that plans for environmental protection measures, measures for the optimal use of land resources, control over the state and reproduction of soil fertility, their implementation can only be carried out on the basis of complete information about the state of the environment and, especially, the soil cover.
- The optimal form of these works is a periodically repeated comprehensive soil-agrochemical survey of the entire area of agricultural land in Russia, including soil, agrochemical, biological, agrophysical, toxicological, radiological and phytosanitary survey (Akimenko et al., 2019; Aparin, 2012; Belitsyna et al., 1988; Odabashyan et al., 2017b; Prokopchuk et al., 2018; Rosstandart, 2011; State Standard of the USSR, 1984, 1985a, 1985b, 1991; Valkov et al., 2004a; Valkov and Zharkova, 2008; Vorobyova, 1998).
- When improving the methodology of comprehensive monitoring of soil fertility of agricultural lands, along with reflecting traditional provisions, it is necessary to take into account the need to: expand the set of controlled agrochemical and ecological-biological indicators of soil fertility for its more complete assessment and increase the efficiency of using fertilizers and other elements of farming systems; develop rational (optimal) levels of fertility of the main types, subtypes and varieties of soils according to an expanded list of indicators for leading agricultural crops; develop and conduct comprehensive monitoring of soil fertility, necessary for the transition to ecologically and economically sound farming systems.

- Scientific approaches to the timing and technique of soil sampling, rational levels of indicators of the properties of various types and varieties of soils, taking into account the requirements of cultivated crops and types of crop rotation, comprehensive assessment of soil fertility, etc., need further improvement.
- Adjustments based on the results of operational monitoring of integrated crop protection technologies against weeds, pests and diseases, timing and doses of fertilizers during fertilization, mechanical tillage, as well as making decisions on irrigation or regulation of the drainage system will increase crop yields by 25% or more, reduce costs for the production of crop products, and improve their quality.

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