Cycles of living and bio-inert systems in soil formation

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Abstract. Material and energy cycles in living systems of phototrophs and heterotrophs, and in inert systems of the mineral base of soils have significant differences. As a result of soil formation and weathering under natural conditions, soils lose some of the nutrients due to the removal of moisture with an intrasoil and subsoil current, but in agricultural use with a commodity part of the crop. The result is a depletion of soils, their aging and a decrease in fertility. Soils successively pass through the stages from birth on the initial parent rock to mature soil, aging, natural death and neorock. The stage of menopause of soils does not exist as equilibrium and which can last immeasurably for a long time. Soil, like any other system, cannot be in equilibrium if there is an influx of energy from outside. In the historical cycle under unchanging conditions of soil formation, time is the main factor in soil formation.

The agricultural sector of Russia has entered the new millennium with a number of pressing problems, the main of which are food and environmental one. This is due to the increasing degradation of the soil cover, which causes enormous economic damage to the country, worsens the social conditions of people's lives [1,2]. High rates of degradation are also characteristic of the soils of the Central and Western Ciscaucasia [3].

Soil degradation should be understood as a gradual deterioration in soil properties caused by a change in soil formation conditions due to natural causes (for example, the onset of forests or dry steppe on chernozems) or human activities (improper agricultural technology, pollution, etc.) and accompanied by a decrease in the content humus, the destruction of the soil structure and a decrease in fertility. These are significant, but far from the main reasons for the decrease in the productivity of the soil cover. In addition, they are not ubiquitous, but the local nature of the manifestation. The main reasons are hidden in the violation of material and energy flows between the radiant energy of the Sun, living, mainly plant, organisms and inert soil matter. V.I. Vernadsky [4,5] noted that “between them and the inert substance of the biosphere there is the only continuous material (energy) connection that goes on continuously during breathing, nutrition, and reproduction of living matter, the main one for its existence: the migration of atoms - chemical elements - from inert bodies biospheres into living natural bodies and vice versa - biogenic migration of atoms. It manifests itself in the form of movement - the departure and arrival of certain chemical compounds and individual chemical elements - from living matter and into living matter in the processes of nutrition, respiration, secretions, reproduction, characterizing living matter. Since the soils are open biocosal bodies, it is natural that every year they lose part of the biogenic elements due to the removal of moisture with a gravitational current, and also in the commodity part of the crop in agriculture. Over time, the natural supply of elements of the plant’s mineral nutrition is
irreversibly reduced, which leads to the weakening and, ultimately, complete cessation of the material and energy connection between living organisms and inert substances.

The study of material and energy cycles individually and in the relationship between living and inert substances is of great theoretical and practical importance, because it underlies the conscious management of not only plant fertility, but also the ecology of the environment.

The main and virtually inexhaustible source of energy on Earth is solar radiation. Among the phototrophs, the main transformers and drives "canned" radiant energy of the Sun are plants, which through photosynthesis can accumulate energy in the form of various products. The plants create food from inorganic matter of the soil and air and in the flow of organic matter from outside is not needed, which was proved by J. von Liebig [6]. Starting point of photosynthesis is the photolysis of water according to the scheme: 2H₂O + 4 hv → 4H⁺ + 4e⁻ + O₂. In fact, photolysis of water is the key to the whole process of photosynthesis, as it is at this stage the quantum energy of the Sun is converted into electrochemical reactions (H₂O) and is used for production of electric "horses" pulling the whole range of biochemical reactions on the main stage of photosynthesis, aimed at obtaining and accumulation of end products.

A material-energy cycle is completed with the formation of the generative organs with the purpose of procreation, that is the main task of all organisms. The overall productivity of the cycle is determined by the mass of the individual plant in the final at the annual plants, and its amount of many years.

Material-energy path from photosynthetic microorganisms is generally similar to the same process as that of the plants, however, the source of hydrogen may be different. For example, photosynthetic purple bacteria use in photosynthesis is not hydrogen: water (H₂O) and hydrogen sulfide (H₂S) and as a by-product emit no oxygen and sulphur: 2 H₂S + 4 hv → 4H⁺ + 4 e⁻ + 2 S.

In this article the attention is paid only on the first stage material-energy cycle of photosynthesis. In General, the photosynthesis consists of a large number of electrochemical reactions that occur both in the light and in the dark. The latter are called "dark reactions" of photosynthesis. The total productivity of photosynthesis (the harvest mass) depends on the availability of water, ash the batteries and the ambient temperature.

Organotroph is not able to directly use radiant energy from the Sun. Nature has solved this problem differently: they use hydrogen from food, mainly sugars, created by the phototrophs. The "carriers of the hydrogen serves as a group of chemical compounds, among which the most important is nicotinamide dinucleotid (NAD). NAD not only carries the hydrogen, but "rips" the hydrogen atoms of the oxidizable food molecules. Every time the NAD molecule picks up two hydrogen atoms, while one of them split into two charged particles: a proton and an electron. Moreover, the negative electron remains attached to the carrier molecule, and the positive proton (hydrogen ion) goes into solution" [7].

In aerobic conditions the process is accompanied by the power of organotrophic cell patient-tion. V. P. Skulachev [8] notes that in the breathing process "more than 90% which people absorb guided keys of oxygen is restored to the water by attaching to O₂ four electrons and four protons. The process is catalyzed by enzymes oxidases: O₂ + 4 e⁻ + 4 H⁺ → 2 H₂O. A much rarer occasion – the introduction of one atom of the oxygen molecule at one time or another organic compound". And further: "Different functions of cell respiration can be divided into four groups: 1) storage of energy in the converted form of ATP or proton potential; 2) the dissipation of energy as heat; 3) the formation of substances useful to the cells; 4) cleaning substances, whose presence in the cell is undesirable". However, we can assume that in the process of supply of oxygen organotrophs performs mainly as a terminal acceptor of the "excess" protons and electrons. In General, the material-energy cycle organotrophs not very effective, as is accompanied by large heat losses.

V. I. Vernadsky suggested that "to distinguish in the biosphere three types of natural bodies: living bodies (for example, plants, microorganisms, animals, etc.), inert bodies (for example, rocks, minerals, etc.) and body bio-inert (e.g. soil, lake water, etc.). The transition of living bodies in the body of bioinert happens after they die due to the process a mine-opening a country's own and humification. As a result of these processes, there are two groups of new minerals - salt and humus, which V. I. Vernadsky called organogenic carbonic mineral. Inert minerals of the parent rocks go to the category of bioinert
The process of weathering of rocks is a biogenic process that usually is not taken into account. The fundamental difference between the bio-inert mineral and organic growths from the original minerals of the parent rocks is that they are products of life and constantly created from the material residues of plant nutrition and soil microorganisms since its inception to natural death. The result of the soil, as the body bio-inert, compose three groups of minerals: maternal inherited, newly formed and organogenic. And, with aging of the soil, the proportion of newly formed increases, and the residual organic maturity, that is actually humus, reduced eventually to near zero.

Schematically the material and energy conversion cycle of the parent rocks in soil formation consists of the following stages: 1-the destruction of the original mine-Rahl → 2 - the formation and accumulation of intermediate products → 3-the formation and accumulation of newly formed minerals. The composition of the original minerals depends on the quality of the parent rocks, but in most cases they constitute the basis for the aluminosilicates of igneous and metamorphic origin. During weathering in the process of root nutrition of plants in the residual phase, they form minerals of kvartsi-quantum groups and intermediate clay minerals of the montmorillonite group and various mixed-layer formation. Due to the peculiarities of its structure, the minerals of this group possess effective ion-exchange properties. They absorb and keep it from leaching the cations of calcium, magnesium, potassium, sodium, ammonium and some trace elements, enzymes and a range of soluble organic compounds – proteins, fats, and microbial bodies. Previously, the group minerals of the montmorillonite was attributed to the zeolites. Their significance in nutrition and the plant life is huge. V. V. Dokuchaev noted that "the more soil is zeolite, i.e., silicates, decaying from the action of acids, especially the soil ready for farming culture, the less labor and cost will have to izderžat 'the owner to bring the constituent parts of the soil from an imperfect state to a perfect".

Intermediate group minerals of the montmorillonite is stable in the alkaline soils, commonly rich in carbonates of calcium and magnesium. They are more actively destroyed in neutral and acidic soils and transformirovalsya in hydrology and hydrologist-kaolinite aggregates, which is accompanied by decrease in capacity of cation exchange, the efficiency of insertion of doses of mineral and organic fertilizers. Essentially, this is the first call of the degradation of the productive capacity of the soil, leading to increase of material costs (the need for increasing doses of fertilizers) for crop production. The main reason for the change of alkaline environments on acid – leaching of the carbonate minerals in the weathering process. We should not think, however, that in leached carbonate soils group minerals of the montmorillonite can accumulate endlessly: the destruction of these intermediate minerals occurs in alkaline and calcareous soils, but in the process of weathering, they are replaced by newly formed so that in a particular bio-inert body is maintained by their equilibrium balance.

The third stage is accompanied by accumulation of kaolinite, oxides of iron, aluminum, Tita-on, Nickel and other heavy metals in the residual phase. Their ratio depends on the outcome-tion of minerals in the parent rock and the conditions of weathering, usually in the later stages of soil formation. The degradation of the mineral mass is accompanied by an irreversible transformation of the colloidal complex of soils from acidosis to bacidosis, reducing the exchange capacity, buffering capacity, and increased costs for production agriculture.

A material-energy cycle inert organic matter consists of the following steps: 1 - its formation and accumulation → 2 - mineralization to the final and intermediate products → 3 - humification community of soil microorganisms in food with the formation of humus and mineral elements in the end. In essence, the mineralization is slow burning, which is accompanied by release of heat energy is useless to the transformation of minerals of the parent rocks during weathering. In breaking down the minerals involved only acid products secreted mainly by microorganisms. The value of humus as the main reserve of nitrogen and phosphorus for the root nutrition of plants is greatly exaggerated. First, for the root nutrition of plants is important only that part of organic matter that is mineralized; second, humus refers to persistent organic minerals and is subject to mineralization over a few millennia; thirdly, nitrogen and phosphorus do not belong to humus and microbial mass, which to select when preparing a soil sample for analysis is impossible and it is easily decomposed in acidic and alkaline products used for extraction of humic substances.
In the evolutionary development of the soil since the soil formation process, to complete degradation of its natural mineral foundation runs a series of stages (figure 1). According to the views of S. A. Zakharov in the initial stage is the formation of small humus horizon and, at the stage of adolescence – the formation of the transitional horizon, on the maturity stage ends with the formation of a complete profile.

In this way the 1-st stage – the beginning of soil formation. There is a settlement of vegetation on the original soil-forming rock and the accumulation of organic matter.

The 2-nd stage – the accelerated soil formation. The formation of the upper genetic horizons begins; the main soil characteristics and differentiation of the profile appear.

The 3-rd stage – delayed soil formation. The formation and development of the same characteristics and properties continues. Soil fertility increases.

The 4-th stage – mature soil. The formation of the soil profile is nearing completion. Soil has the maximum amount of organic matter, nutrients. Properties and soil conditions are optimal. There are no significant differences in the quality of the mineral basis of soils and soil-forming rocks. Fertility reaches the highest level. This 4th stage is inconsistent with the general ideas of the Russian theory of climax (equilibrium) period of soil formation. Is it possible to achieve any equilibrium and constancy in open biological systems with a constant inflow and outflow of matter and energy?

Stage of menopause, allocated by A. Rhode, in our opinion, does not exist as equilibrium and can continue infinitely long time. The soil, like any other system, is not in the equilibrium state, if there is a flow of energy from the outside. Most likely this stage is characterized by a certain stabilization of the arrival and departure of nutrients into living matter and from living matter back into the soil in the processes of nutrition and respiration without changes in basic properties of bio-inert body, obtained at the stage of maturity. Fully, judging by the rest of the Stavropol region, the small areas of virgin soil, the stage of climax is characteristic for soils of automorphous type of development under natural, multi-species herbaceous vegetation, root system which is distributed over the entire soil layer. With the involvement of virgin soils in arable land and cultivation of single-species, mainly cereals crops, 80% of the root system, which is concentrated in the arable horizon, climax tranquility is disturbed. Mineral weight of the arable layer is exposed to increased wear and, although the edge of virgin soil involved in the cultivation relatively recently (150-200 years), there has been a process of accelerated aging and separation from the underlying horizons. It manifests itself in the deterioration of chemical, physical, physicochemical and other functional properties of the arable layer.

Figure 1. General scheme of soil evolution.
The 5-th stage – soil aging. The weathering of minerals leads to an increase in the number of newly formed minerals of a poor chemical nature. The pH, the content of labile forms of nutrients, organic matter decreases, the properties of soils are transformed. Soil fertility declines. The stage of aging of the soil as a bio-inert body begins with the appearance of significant differences in the mineral base between soil and rock, a decrease in the content of available nutrients, organic matter, the transformation of functional properties, the reaction of the environment, the composition of the PPC, the structure, absorption capacity, and the accumulation of a number of heavy metals, the homogeneous structure of the soil profile and other features inherent in the soil of the climax stage. In general, aging is a slow degradation of the basic properties of the soil due to the decay of the initial minerals and the accumulation of the final species without changing the conditions of soil formation - climate, topography, depth of groundwater, etc. For the complete cycle of soil formation, time and preservation of eluvial conditions are necessary; on gentle slopes, flat flushing leads to mineral rejuvenation of the soil due to the approach to the surface of less weathered horizons; in closed depressions and floodplains - accumulation of weathering products of poorer chemical composition.

And the 6-th stage – the death of soils. The mineralogical composition of soils and soil-forming rocks is radically different from each other. The bulk consists of newly formed soil minerals. In humid tropical conditions - bauxites, siderites, kaolinite. In moderately wet and arid conditions - quartz and opal (SiO2, SiO2.nH2O.) Soil can no longer satisfy the needs of plants in the elements of mineral nutrition, it perishes, becoming a neorock.

This scheme of evolution can be successfully applied only in the wet zone. In conditions of arid or moderately moist climate the duration of the stages is longer and soil death cannot be expected, because during this time lowering and uplifting of land, erosion processes and other occur. There one can observe only the accumulation of weathering products of poorer chemical composition.

In conclusion, it should be noted that the soil as a bio-inert body according to V. V. Dokuchaev “There is a function (result) from the parent rock (soil), climate and organisms, multiplied by time.”

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