Carpathian Journal of Earth and Environmental Sciences, May 2014, Vol. 9, No. 2, p. 209 - 217

CYCLES OF SUBSTANCES AND ENERGY AT GEOSPHERES INTERFACE – FLUXES CONDITIONING THE SOIL AND LIFE

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Abstract: It is argued the cosmogeobiotic nature of the pedosphere (or of soil cover), and the absolutely necessary involvement of the substance and energy fluwes in the formation and existence of soil, new aspects that make complet knowledge in this field. The soil is cosmic due to solar main source of the energy involved in soil genesis and due to cyclic development of this process. It is telluric (geo) due to geological origin of the mineral components of soil and their movement on Earth's surface under influence of the gravity. It is biotic due to intimate implication of the biota in soil formation and dynamics. Four fluxes of substances and energy are indispensable for soil existence: water, air, nutrients and energy fluxes. The energy flux, unlike the other fluxes, is not cyclic, but one-directional, the solar energy being permanently renewed. A new scenary of soil formation and development is presented. In this new synergic scenary of pedogenesis the above mentioned fluxes of substances and energy (information included) are involved in the soil genesis, developing the present factorial concept of the pedogenetic processes and factors in soil genesis. The soil is a fundamental natural and indispensable resource of the Earth because it fulfils very important functions by which is involved in the most essential features of the environment and life, as hydrological cycle, nutrients cycle, surface sediment circulation, global climate, environment stability, creatures health. All these show not only the complexity of the pedosphere, but also the planetary importance of the pedosphere because any perturbance in the soil cover will affect seriously biosphere, the environment and implicitly the society with unforeseeable consequences.

Key words: soil as cosmogeobiotic formation, fluxes of substances, energy and information, synergic scenario of pedogenesis, soil implication in Earth's events.

1. INTRODUCTION

The soil, or the pedosphere, a thin layer at the surface of the Earth's crust, is a complex geoformation constituting an intimate interface of lithosphere, atmosphere, hydrosphere and biosphere, acting under influence of environmental conditions. Comprising living creatures the soil cannot exist without continuous addition (consumption) of water and other substances, as well as energy. Four main fluxes – of water, air, nutrients and energy – are absolutely necessary in order to soil function.

On the other hand, the soil has an important role as intermediary – at Earth's crust surface – in the continuous interactions between environmental factors and energy and substances fluxes, being involved in all cycles and processes happened in and between mineral and living world.

The purpose of this paper is to emphasize the essential role of the fluxes of energy and matter at the land surface at the contact among geospheres, yet not quite underlined in connection with soil genesis and life carrying on.

2. SUCCINT DEFINITION AND HISTORY OF SOIL

In present, the soil is considered as a natural body or system formed at Earth's crust surface by rock weathering and transformation due to geologico-geochemical, biologico-biochemical and pedomorphogenetic processes, cyclically carried on

long term, under influence of environmental factors (climate, organisms, parent rock and relief); this conception was first time given out by Dokuchaev as early as 1883.

This actual perception of soil was preceded of other thoughts. In times past the soil was perceived as loose layer, but firm, at Earth's crust surface. Concurrently with sciences and agricultural developing, begining with the XIX century, the soil was considered either "arable land", used for plant growth, by agronomists and agrochemists (Thaer, 1809; Mitscherlich, 1931; Demolon, 1932; Liebig, 1840), or "vegetal earth", produce of the rock weathering in various natural conditions (Fallou, 1862; Ramann, 1911; Hilgard, 1906).

The actual concept of soil as natural independent body (Dokuchaev, 1883) was developed further in Russia by Sibirtsev, (1909); Glinka, (1914); Vernadski, (1926); Rode, (1955); Kovda, (1973); Gerasimov, (1964); Fridland, (1972), and others; in Europe by Robinson, (1937); Stremme, (1926), and Russell, (1961); and in U.S.A. Marbut, (1935); Kellogg (1938); Jenny, (1941) and Smith, (1983).

This Russian concept was regarded as revolutionary, because it made possible a science of soil (Soil Survey Staff, 1975; 1999; Soil Survey Division Staff, 1993). This concept was up-to-dated by American soil scientists and a new soil taxonomy based on diagnostic criteria was elaborated (Smith, 1983), known as Soil Taxonomy. F.A.O. (Food and Agriculture Organization) contributed in a large measure to the extension of this concept by encouraging the international co-operation for the world soil map compilation (Finke et al., 2001) and then the preparation of the World Reference Base for Soil Resources (last edition IUSS WRB-SR, 2006). According to Lovelock (1993) the soil can be considered as a model for the entire Earth.

Lately, the idea of soil as information source was developed and Geographic Information System (GIS) also.

In Romania, Murgoci (1911) shows that "the soil is a body which also contain life… undergoes continuous changes; so that this formation is a bridge of transition between the inert, inorganic world and the world of the organized individuals having life" and Chiriţă (1974) considers the soil as living organism, quoting Vernadski. Also, Florea (1989) develops the idea, showing that soil has attributes of living body which are confered it by the soil biopedoplasma consisting of coloids and microorganisms of soil.

The soil approach from the engineering point of view and also reel estate were not taken into account because these aspects belong to other branch of science.

3. SOIL, COSMIC-TERRESTRIAL FORMATION

In this period of globalization it is useful to specify the soil or pedosphere position in the framework of Terra and Cosmos. An idea in this sens results from the figure 1; the pedosphere can be understood only by studying it as formation that depends on solar energy and other cosmic radiations and on terrestrial chemical elements, to which the gravity force joins. Moreover, the cyclic activity developed at various intervals – days, seasons, years, centuries, millenia, etc. – within pedosphere at lithosphere – atmosphere – hydrosphere – biosphere interface is essentially influenced by the cyclicity of all the events from the Cosmos, so that changes of various nature – cosmic, geological, climatic, etc. – give rise according to a cosmogenic program (domain in which the science takes contact with the theology).

The biosphere, which plays an important role in the pedosphere formation and development, has itself a cyclic dynamics (the biorhythm) which reverberates on soil (pedosphere).

Excepting some changes, the major part of changes cannot be perceived at human life scale, but they are in a large extent memorized as "information" in geological deposits, in the fossilised skeletons of various old creatures, in the succession of loesses and fossil soils, in the relict features of some soils, in the artifacts and archeological vestiges, etc.

The cosmic influence is felt in biosphere and pedosphere not only directly by cyclic events (climatic changes, tectonic movements, etc.), but also through accidental events (active volcanos, meteorite concussions, etc.) which could cause great changes of factors that control the living and evolution of the vegetation and soil.

In fact, the existence and dynamics of soils, as well as all the activities on Terra, have at their basis the cyclic development of the cosmic events and also the transformations of matter and energy produced in space and time on terrestrial crust.

4. SOIL CONSTITUTION AND ITS HIERARCHICAL SYSTEMIC STRUCTURE

The soil is considered at present (Buol et al., 1997) as a complex dynamic system in an unceasing transformation under influence of the changes (variations) of the inner and outer factors or forces

(although at human life scale the changes concerning soil features are not perceptible excepting the modifications of some soil properties as moisture, temperature, compactness, soil solution reaction, or nutrient contents that can be periodic discernible some of them even daily).

As complex system, the soil is composed of a set of soil subsystems having increasing organization levels and forming a hierarchy (Dijkerman, 1974; Smeck et al., 1983; Florea, 1998; 2010; Florea et al., 2013), each subsystem with its regularities and specific character, but being subordinated to the higher subsystems and subordinating the lower subsystems. In such hierarchy the subsystems begin with atom and molecule level and pass through different levels of soil particles and horizons organization to the polypedon level which corresponds to the soil individuals (soil entity). In fact, soil entity (polypedon) is a system that integrates into a whole all the soil subsystems of various degree of development (organization).

5. THE INDISPENSABLE FLUXES FOR SOIL SYSTEM

The soil-system dynamics and the essential soil characteristics (fertility included) are close related to the fluxes of matter and energy, necessary to carry out its functions (Volobuev, 1976). The following four fluxes represent conditions *sine qua non* for the soil-system existence (Fig. 2).

Water flux, carried out through the agency of hydrologic cycle in nature, cycle to which the soil itself participates by the rainfalls received and partially stored, by land surface running of water and hydrological network supply, by water percolation and groundwater supply, by evapotranspiration and clouds supply with watery vapours.

The water from soil is essential because it permits the interreactions among mineral, organic and living matter and soil development. It is often compared with the blood of the living organisms; it transports the nutrients for plants, becoming soil solution.

Air flux, achieved by unceasing change of gases between soil and atmosphere, is necessary for the refreshing the soil air, richer in CO_2, with atmosphere air richer in O_2 necessary for the soil respiration processes and other oxidation processes. This flux (cycle) takes place by air movement through aeration soil pores, which can be compared with the lungs.

Nutrients flux is carried out by biogeochemical cycle by which the chemical elements from organic matter annually incorporated in soil are mobilized in a great extent by mineralization and humification processes of the dead organic matter (to which formation the soil itself participated) with liberation of CO_2, NH_3, H_2O, etc. as well as nutrients that are retained in soil by ionic exchange processes or other processes.

The *soil metabolism* has the most important role in this nutrients flux, by which the "digestion" of organic remnants is achieved, but the "motor" of this metabolism of soil is represented by the soil edaphon, by the creatures from the soil, without which the soil itself cannot exist according to Kellogg (1938) (it plays the role of the digestive apparatus).

These nutrients pass on gradually in soil water forming soil solution with which the plants and the edaphon are supplied (with water and nutrients) in the framework of this cycle.

Solar energy flux (light and heat) is necessary for the photosynthesis and for evapotranspiration in order to maintain the temperature at a level that can make possible the photosynthesis process.

The solar energy flux is one-directional; the accumulated energy in the synthesized organic matter and consumed in the trophic chain does not return, does not form a cycle, but it is dissipated in the environment. The solar energy is permanently renewed by the Sun. Therefore, this energy flux is different from the other fluxes that form cycles through which take place a re-circulation (re-cycling) of substances, very important for the life perpetuance.

6. A SYNERGIC MODEL OF SOIL DEVELOPMENT

The fluxes of matter and energy being indispensable for soil dynamics entail a new, a synergic detailed model of soil development (Florea, 2013). A simplified outline of this model is presented in figure 3. This extended concept of the synergic interactions of fluxes, processes and conditions (factors) *completes the actual concept of pedogenetic factors and processes (factorial model) concerning soil formation, with the integration in this process of the above mentioned fluxes of matter and energy*, the circulations (the cycles) of water, air and other substances and energy playing an important part on soil dynamics.

The pedogenesis takes place on the *one hand from a mineral geological substratum* (parent rock or parent material) that conveys to soil (as heritage) some features which can be modified by pedogenetic

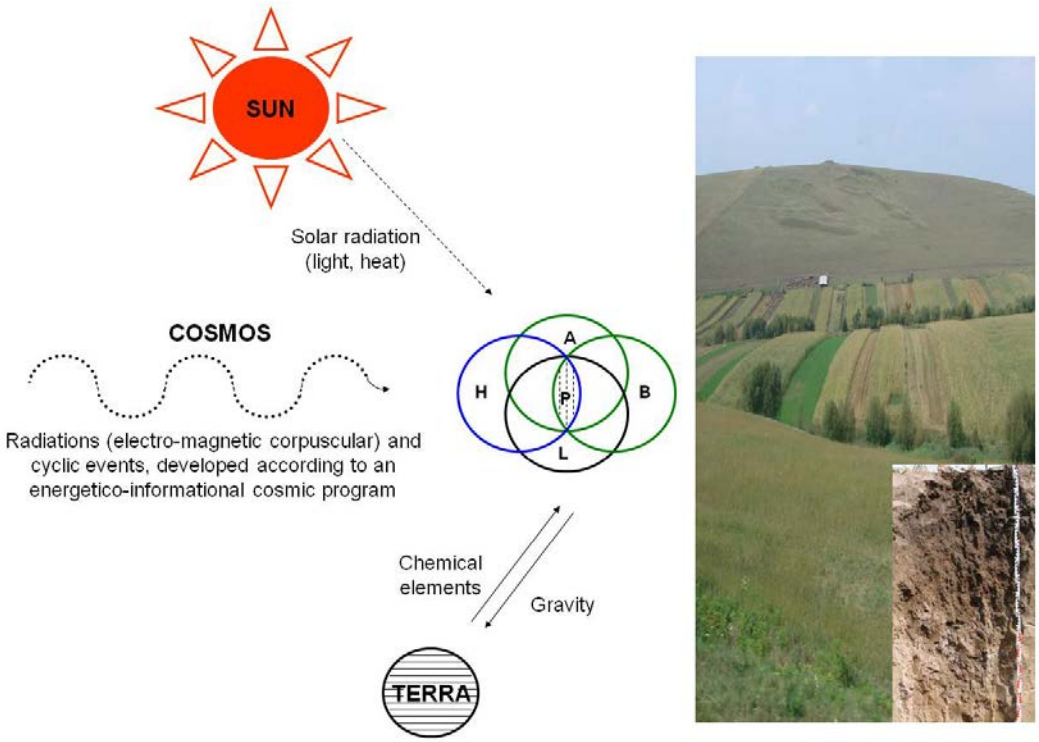


Figure 1. Soil, terrestrial formation cosmic influenced

Soil (pedosphere, P) situated at Earth' crust surface, as interface among lithosphere (L), atmosphere (A), hydrosphere (H) and biosphere (B), acts under influence of solar energy, gravity and Earth's chemical elements, and also under influence of cyclically cosmic radiations and events developed according to an energetico-cosmogonic program. The parent material can be autochthonous or allochthonous (previous weathered, transported and sedimented)

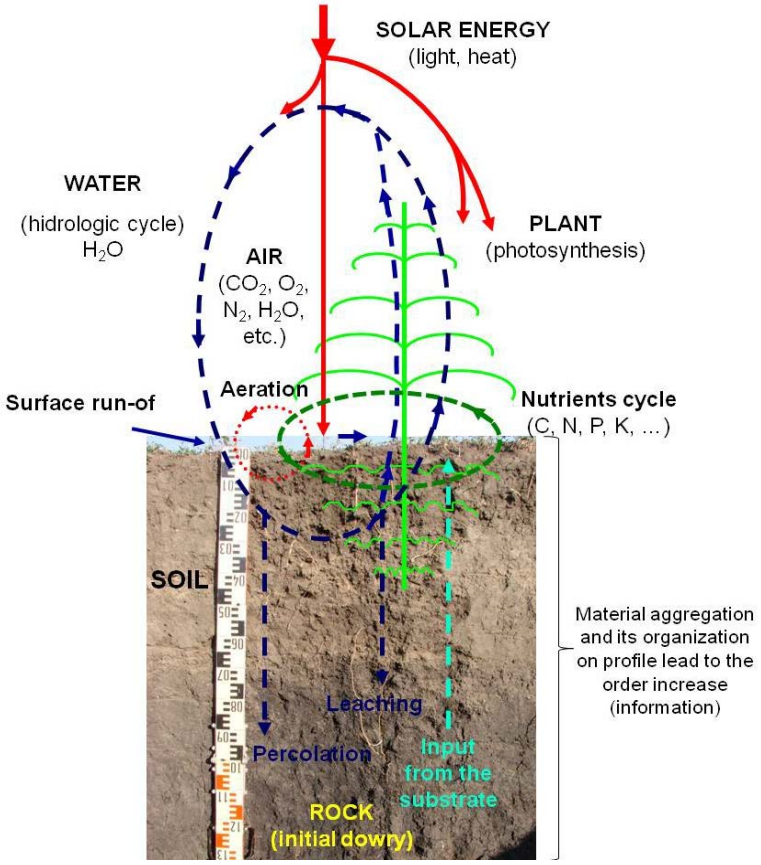
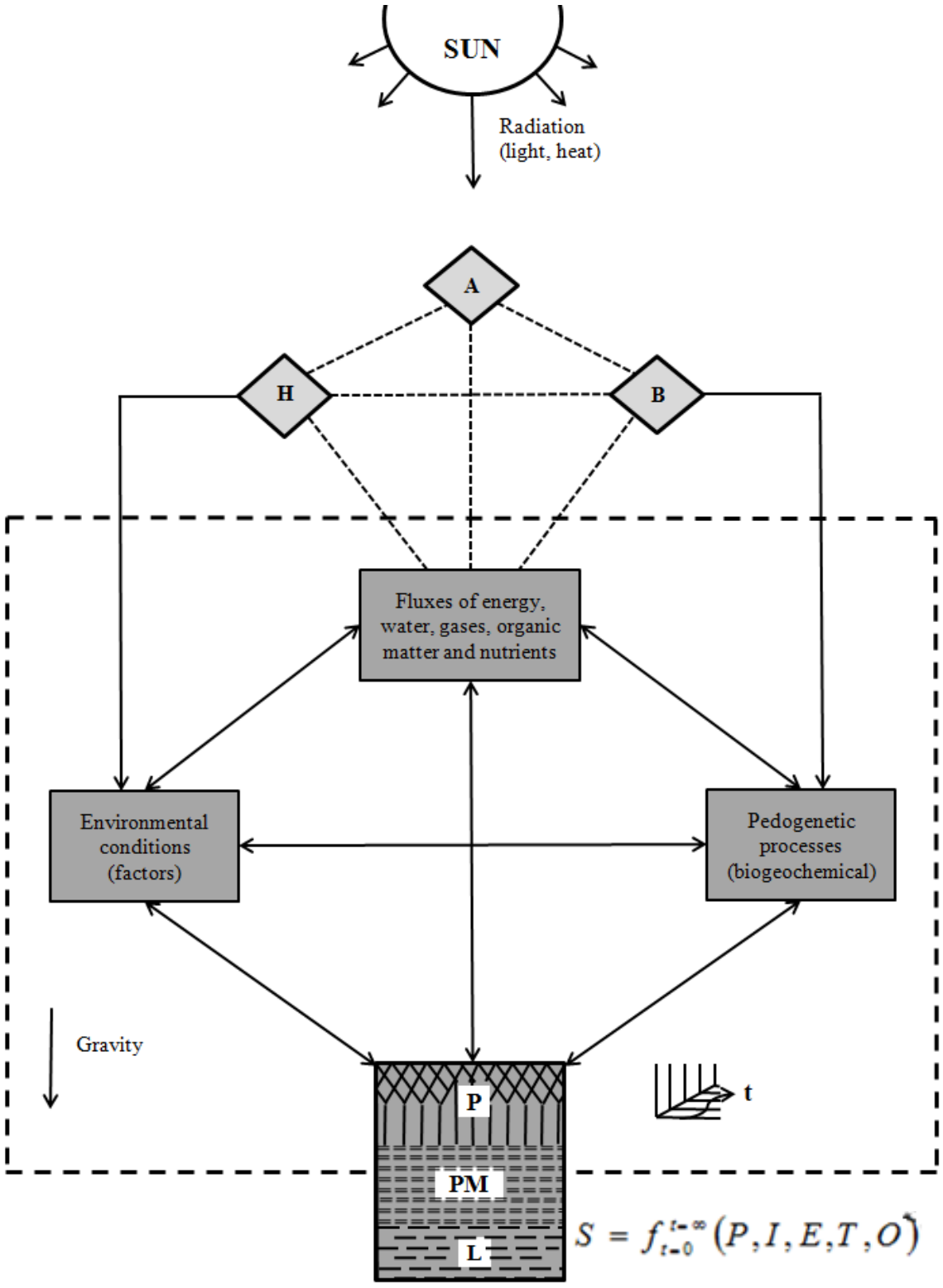


Figure 2. The main fluxes of substances and energy which provide for soil life as complex natural system

(In order to live, the soil - as a creature, though is not a living organism – absolutely needs water, air and organic matter from which obtains energy and nutrients involved in life processes.)



A - Atmosphere H - Hydrosphere B - Biosphere
P - Pedosphere PM – Parent material L - Lithosphere

Figure 3. A simplified outline of soil genesis as synergic continuous interactions of the fluxes of energy and substances with pedogenetic processes, cyclically developing in close interdependence with environmental conditions (factors)

processes in somewhat extent, and on the *other hand on the base of the recurrent flux of organic matter yearly delivered by vegetal cover* of which will depend on in a great extent also the humus formation and nutrients cycle, *as well as on the base of the recurent fluxes of water and air* of which will depend on the hydric and air soil regimes

The soil parent material, respective the soil

geological fund, has an important role from the beginning of the pedogenesis being not a merely pedogenetic factor; it conveys to soil (as heritage) the mineral substratum that can be very various, orientating different the soil features. The parent material can originate either from compact rocks (autochthonous parent material) or from transported material and then sedimented in new deposits (allochthonous parent material). The pedogenesis in the two kind of parent material are in a extent measure different, especially due to fact that allochthonous parent materials were undergone before to an ancient process of weathering.

The two immense worlds, very different, namely the *world of Silicon combinations specific to mineral kingdom and the world of Carbon combinations specific to living kingdom join together in soil for the life support* (Florea, 2013) through agency of water that mediates all dynamic relations sustained by solar energy.

Concerning the changes within soil (formation of micro- and macroagregates, leaching and accumulation of constituents, enriching or depletion, etc), these ones take place as a consequence of a very many and complex reactions and processes (physical, chemical, biochemical, metabolic, eluvial-illuvial, etc.) under the continuous circulation conditions (fluxes) of substances and due to permanent exchanges of energy and substances with the environment.

Most of these reaction and processes are reversible or recurrent (Yaalon, 1983; Arnold et al., 1990). But this reversibility are not perfect so that yearly minute changes, ΔS, imperceptible, but totalized long time result in the differentiation of the morphological features and soil properties on vertical, and finally in soil individualization.

To these ones the gravity force (attraction) is added, directing the circulation of water, sediments and soil materials.

7. PEDOSPHERE MULTI-FUNCTIONALITY

The soil, respective the pedosphere, mediating the interrelations and interactions among geospheres (Ruellan, 1985; Montgomery, 1995), plays a main role for the whole nature and society life by the functions that fulfils. For this reason, the soil (pedosphere) is regarded as a fundamental resource of the mankind (Tiurinkonov & Fedorov, 1990), absolutely indispensable for society and nature (Kovda, 1978).

The main functions that fulfil the soil, very important for nature, biosphere and society, are (Kovda, 1985; Dobrovolski & Nikitin, 1986; Florea, 1991; Blum, 2005):

- function of water reservoir and provider, and also of water regime regulation, in the same time participating to the hydrologic cycle in nature by distribution of the rainfall on land between surface run-of and infiltration, storing and percolation through soil;

- function of air reservoir and oxygen provider (for respiration and other oxidation processes), and also of air regime regulation by air refreshing through exchange with the atmosphere (of whose composition is so influenced);

- function of the plant supply with nutrients in available forms (by soil solution) and continuous cycling of nutrients (biogeochemical cycles) – essential for life perpetuance – achieved by decaying of the vegetal and animal remnants through soil edaphon; the soil is situated at the beginning of the trophic chain in biosphere, so that any perturbation of soil processes has repercussions for all the creatures;

- functions of environment protection by filtration of percolated water, immobilization of some pollutants or decomposition of some noxious organic substances (soil function of purification);

- function of purveyor and partial accumulator of energy by recurrent receiving of dead organic matter, energy loaded, and its gradually decomposed with partial piling of humic substances,

- together the plants and adjacent atmosphere the soil makes up a “reactor” at Terra scale in which the conversion of solar energy in biochemical energy of organic matter (by photosynthesis) takes place;

- function of recording of some information on soil environment and on the historic past, under the form of “codes” within “soil memory”, as well as the function of conservation of some archaeological vestiges;

- function of foundation or emplacement of various buildings, installations, understructures, etc. necessary to human activities; sometimes, the soil may be used as building material or raw material.

By all these functions (Fig. 4), the pedosphere – as natural formation which makes the link between inert matter and living matter – is very intensive involved in:

- global climate, due to C re-cycling, emission of gazes with greenhouse effect (watery vapour, CO_2, NO_x, CH_4), as well as in the participation to the thermic balance correlated with the hydrologic cycle;

- water cycle in nature, by water accumulation in soil, the ground waters supplying, the water run-of at land surface and implicitly the river supply, and also in the chemical composition of surface and ground waters;

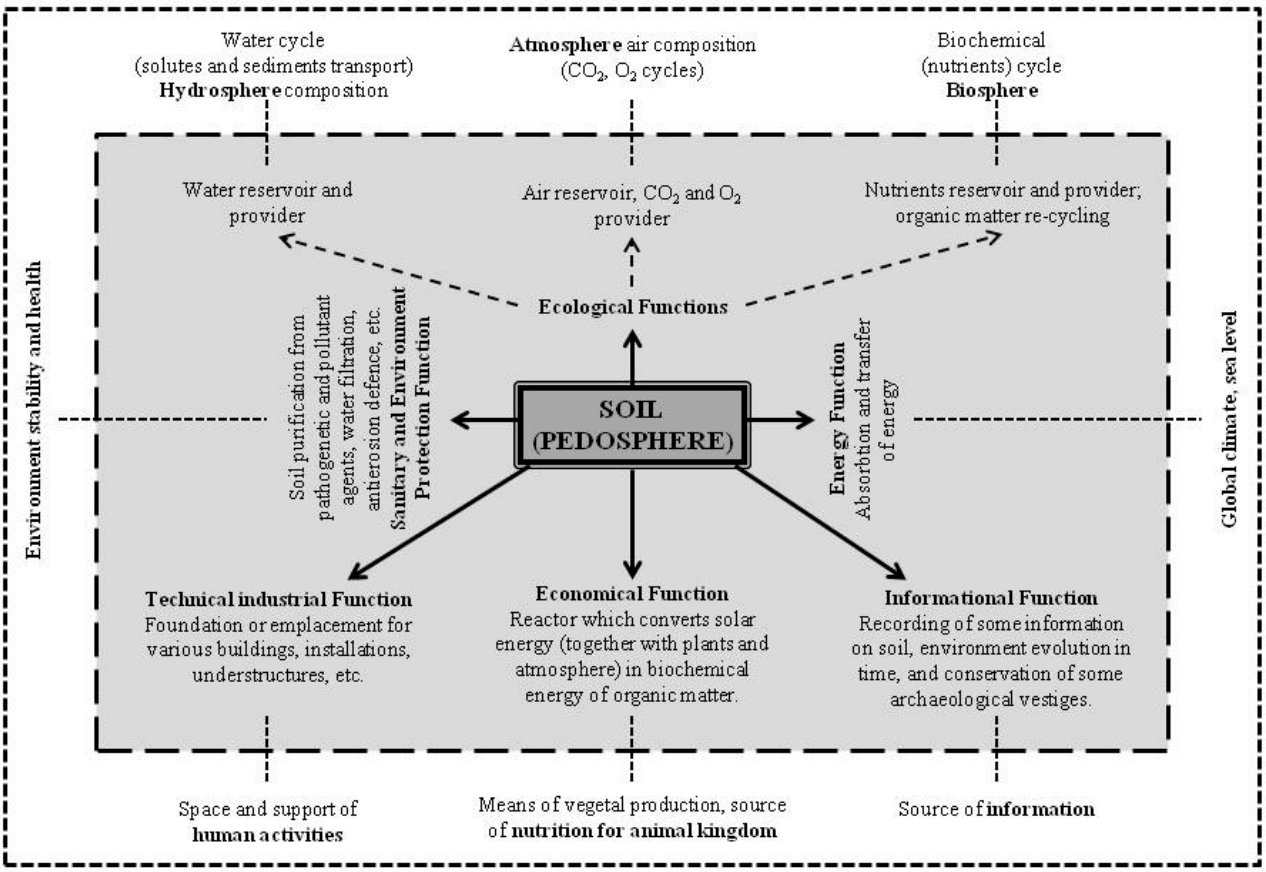


Figure 4. Soil multifunctionality. Through its many functions the soil mediates the interaction between the "great geological cycle" and the "litle biological cycle" contributing to the selecting and keeping the "biophile" chemical elements (nutrients) in soil and to the conveying the soluble chemical elements to ocean

- natural cycle of chemical elements; its disturbance can lead either to soil depletion with unfavorable consequences to welfare or to soil pollution or water reservoir eutrophication;

- surface sediments circulation intensified generally as a consequence of soil erosion increase due to the inadequate use of soil, having undesirable effects correlated with the silting of water reservoir or fertile soils, or determining the worsening of the water quality and different disfunctionalities for network of roads, localities, etc.

- although the soil is not a direct nourishment for creatures, nevertheless the health of these ones depends on in a great extent from the soil nature (the soil being at the beginning of the trophic chain), because the quality and proportion of the nutrients (from nourishment originated from soil) are essential for vital processes and for the immunity system of all living organisms.

All these aspects stress the important role of the soil for the environment, biosphere and society (Kellogg, 1938; Kovda, 1978; 1985). The soil, a result of the action of the living organisms on mineral substratum, became itself a coordinating factor of life. "The soil constitutes the most precious richness, the most valuable heritage, which has to be known, recognized, protected, preserved and turned to account at its true potential" (Hera, 2006).

8. CONCLUSIONS

For the first time, there are unequivocal underlined that the soil (pedosphere) is a natural cosmogeobiotic formation at the Earth's crust surface and needs continuous fluxes of energy and substances in order to function. It is cosmic due to the main source of energy (solar radiation) involved in soil genesis and due to cyclic development of this process. It is telluric by the geological origin of the mineral components of soil and their circulation on Earth under influence of gravity and in the same time it is biotic due to implication of biosphere in soil dynamics and cycles.

Four fluxes of substances and energy are indispensable for soil existence: water, air, nutrients and energy fluxes (cycles). Unlike other fluxes, the energy flux (from Sun) is not cyclic but one-directional, the solar energy being permanently renewed.

The soil (pedosphere) is not a simple Earth's

epiderm, as some people consider, but the bioactive layer from the terrestrial crust surface, highly organized, resulted by transformation of the geological substratum through the biosphere action and solar energy; this layer makes the connexion between anorganic world and organic (living) world in which the convergency and interconnexion of the fluxes of substances, energy and information and their distribution at land surface take place.

The parent material (geological fund) is more than a pedogenetic factor because it influences from the beginning the pedogenesis because it offers to soil the mineral substratum with different features (as heritage). This parent material can originate either from compact rocks in situ – autochthonous parent material – or from transported and sedimented deposits – allochthonous parent material. In the last case the soil development has an apart march because the soil formation began from an already weathered mineral material.

The soil is really a fundamental natural resource of the world, because it fulfils very important functions and is involved in the most essential events of the environment and life, as hydrological cycle, nutrients cycle, surface sediment circulation, global climate, environmental stability, creatures health.

The complex terrestrial and global implications of the fluxes of matter and energy and of the pedogenesis processes, discussed succintly in the paper, show the complexity and the difficulty of research and knowledge, but also the planetary importance of the pedosphere because any perturbance in the soil cover will affect seriously the biosphere, the environment and implicitly the society with unforeseeable consequences.

The better understanding of the nature of soil and its functions, and its role in the environment and society, we hope, will change the people attitude concerning this valuable natural resource.

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Received at: 01. 08. 2013
Revised at: 25. 02. 2014
Accepted for publication at: 14. 03. 2014
Published online at: 18. 03. 2014