Methodological bases of modern soviet soil science and its future development

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SUMMARY

Methodological bases of modern Soviet soil science have been treated in the present article in light of its historical development from DOKUTCHAEV'*s times till present. Two main stages or trends were distinguished within this century of science development: the stage of soil inventary and the stage of soil management. Basic methodological concepts are being considered, starting from the soil definition in its present form, through the concept of soil evolution; the concept of soil as a component of ecosystems of the Biosphere; the concept of elementary soil processes and current regimes of soil formation; the principles of mathematical modelling of soil processes. An attempt was made to correlate the development of soil science with changing historical tasks of socioeconomic development of the country.*

RÉSUMÉ

Les bases méthodologiques de la science du sol soviétique moderne sont traitées dans le présent article à la lumière de leur développement historique depuis l'époque de DOKUTCHAEV *jusqu'à l'époque actuelle. Deux principaux stades ou deux tendances ont été distingués dans ce siècle de développement scientifique : le stade de l'inventaire et le stade de la gestion des sols. Les concepts méthodologiques de base sont considérés à partir de la forme actuelle de la définition du sol et à travers le concept de l'évolution du sol, le concept du sol comme composante des écosystèmes de la Biosphère, le concept des processus élémentaires et des régimes actuels de la formation du sol, et à travers les principes de la modélisation des processus pédologiques. Un essai de corrélation est entrepris entre le développement de la science du sol et les changements historiques des besoins socioéconomiques du développement du pays.*

MOTS CLÉS : Science du sol soviétique. Histoire et concepts fondamentaux. Relation avec le matérialisme dialectique. Inventaire et gestion des sols. Niveaux d'organisation. Développement historique des processus. Rôle du sol dans les écosystèmes. Méthodes de modélisation. Perspectives d'avenir.

BASIC CONCEPTS

Talking about the present state of the Soviet soil science and its methodological basis, it is necessary to proceed from *the history of its development* which started at the eve of the 20th century by V. V. DOKUTCHAEV and the brilliant team of his disciples and followers.

End of the 19th century and beginning of the 20th in the history of science in general, and the natural science in particular, is characterised as a period of vigorous progressive development. The reader is well informed, of course, about the main milestones of the history of soil science, and there is no need to describe it once more in a detail. However, it is necessary to stress once more the point, that the methodological bases of modern genetical soil science were laid down during that period, when the ideas, approaches and methods of *the materialistic dialectics* were put into the service of natural science. The Russian naturalists of that period were basically materialists and dialectics. This is fully applicable to the Russian school of soil science as well, which was initiated by V. V. DOKUTCHAEV.

The classics of Russian soil science—V. V. DOKUTCHAEV, N. M. SIBIRTSEV, P. A. KOSTYTCHEV, P. S. KOSSOVITCH, K. D. GLINKA— as well as their disciples have formulated during the thirty years of 1880-1910 a number of basic principles of genetic soil science, which constitute the theoretical basement of modern methodological approaches:

— the concept of *soil as an independent natural historical body of Nature*, which develops with time from the parent rocks under the influence of factors of soil formation, among which the leading role is played by living organisms;

— the concept of *factors of soil formation* as an interdependent and integrated complex of natural phenomena, under simultaneous and integrated action of which the soil is forming and developing;

— the concept of *historism of soil formation* and of succession of stages of soil formation and evolution;

— the concept of *unity of soil body* as an independent natural body and related to this concept the profile method of soil study, which proceeds from a doctrine of soil profile as a unity of genetic soil horizons;

— the concept of *soil types* and types of soil formation as stages of soil-forming process on the long way of development and evolution;

— the concept of *the present soil cover* as a stage of the global soil cover development in the history of geological evolution of its surface;

— the concept of *soil zones* and zonal types (associations of types) of soils as the main form of organization of the global soil cover reflecting the structure and history of the Earth's surface evolution (1);

— the concept of *soil classification* and systematics as a reflection of really existing in nature bonds (geographical, genetical, evolutionary) between different soils.

It is not difficult to see, that at the basis of these methodological principles there are the main doctrines of the materialistic dialectics:

— of the *priority of the Matter* over the Knowledge;

— of the *Movement* as the main form of existence of the Matter;

— of the *general interdependence and interconnection* of phenomena in Nature;

— of the *causal determination* of natural phenomena;

— of the *knowledge as a reflection* of the surrounding man reality.

The connection of the methodology of modern soviet soil science with Marx-Lenin's philosophy was specifically studied and underlined by a number of scientists (KOVDA, 1970; DOBROVOLSKI, 1980).

An experience of decades of development of the theory of genetical soil science and of the practical utilization of its achievements in agriculture and soil amelioration have proved vitability and adequateness of these basic principles, which did not loose none of their leading role in the methodology of modern soil science. On the contrary, they were developed, deepened, concretized, enriched by subsequent studies and constitute the theoretical basis of the soviet soil science at the present stage of its development.

There is neither necessity nor possibility to tell here the whole complicated and very instructive history of the soviet soil science for the past hundred years. A solid volume is necessary for this endeavour but the magasine article; this is a subject of special capital investigation. However, we shall turn to some historical periods during the following narratives, as the modern doctrines, ideas, concepts and methodological approaches are the result of prolonged and energetic scientific searches and studies, the result of vigorous scientific discussions, some of which took several decades of trials and errors.

TWO STAGES/DIRECTIONS OF SOIL SCIENCE DEVELOPMENT

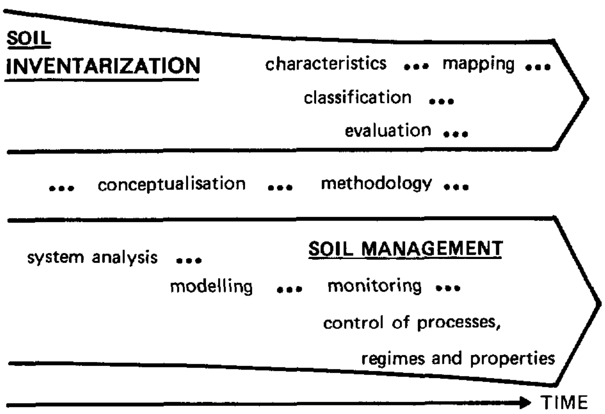
It is possible to distinguish two broad periods in the history of the soviet soil science, which essentially overlap each other in time. They can not be limited by some concrete years: they are rather not the time periods, but sooner the main directions of studies, connected with certain socio-economic

(1) The present understanding of nature and forms of soil zonality is much wider and more rich than the originally formulated doctrine of latitudal regular global zones, but the principal basis of the concept has been preserved.

mandate to science at this or that stage of development of the society. The first period is still continuing and indeed did not loose its importance, but, on the contrary, develops rather actively. The second period have formed itself relatively not long ago and makes only first steps, constituting the basis of future development of soil science.

If the first period may be generally characterized as a *period of inventarization* (characteristics, mapping, classification, evaluation) of soils and soil cover, the second may be also generally characterized as a *period of management and control* of soils and soil cover. A new problem is now before the soil science, which requires new methodological approaches as well.

The relationship of these two qualitatively different stages of the soviet soil science development may be schematically illustrated by two interconnected cones with oppositely directed bases:



We can not say when the first period will stop and will it stop at all or not; most probably, it will continue forever, as endless is the process of knowing itself of the surrounding man reality. We can not say when the second period has started, as its elements may be traced into the very first works of the classics of soil science. However, at some stage we suddenly and unexpectedly recognised *the coexistence of these two stages/directions* and have seen that the second one started to develop quickly involving more and more efforts and resources. The above illustrated relationship finds more and more reflection and concretization in scientific plans and programmes, in the state financing of science, in concentration of efforts of scientists on the solving of these or those scientific problems.

Naturally, the historic development of these two directions of soil science and their concrete relationship was never so smooth and regular as it is shown at the above scheme; vice versa, there were picks and hollows in the activities, there were periods of vigorous development and relative stagnation. The history of soil science is rich in various events.

Presently we are somewhere in the middle of the historic process of interrelationship of two science directions: *inventarization of soils* proceeds intensively, as well as the investigation of their properties; we still do not yet get accurate maps for all territories, we do not yet have generally accepted satisfactory soil classification, we still do not know many things about soil properties and their genesis. However, already accumulated knowledge allowed us to pass into the second stage, to come to *management of the soils and the processes going on in them.* This transition went slowly and inadvertently, hesitantly at the first steps, but it accumulates power more and more as the time passes. Already, a certain theoretical evaluation of this stage of science development is being attempted to make (KOVDA, 1966, 1970, 1977, 1980).

SOIL DEFINITION

The DOKUTCHAEV's genetical methodology based on the principles of materialistic dialectics helped in many respects to the progressive development of soil management. We have in mind, first of all, the DOKUTCHAEV's soil definition and the doctrine of factors of soil formation, which were formulated by him during 1879-1901 (DOKUTCHAEV, 1879, 1881, 1899, 1901).

Being originated at the junction of different branches of the natural science, the genetical soil science has absorbed the methodological approaches of these sciences and, on this basis, has worked out *its own methodology*, at the basis of which there is a dialectic principle of causal interdependence of phenomena which is the central idea of the doctrine of factors of soil formation. Exactly due to such methodological approach, in the genetical soil science from the DOKUTCHAEV's times, not a substrate-attributive definition of the main subject of study, soil, was adopted, but *the functional definition*, and not in the terms of causal internal bonds, but in terms of *external* functional bonds of management:

$S = f\ (cl,\ o,\ r,\ p,\ t...)$.

Although at this approach the internal mechanisms of a process may appear hidden from us, nevertheless we may get enough reliable picture of external functional bonds of a system and its environment. It is well known, that the functional bonds of the system and its environment are particularly important for the processes of management. Such approach permits to describe systems with assistence of *generalized model of two-dimentional vector* (NOVIK, 1964) :

outcome=f (entry).

We did not fully appreciate yet all the consequences of such a "cybernetical" approach to soil definition which further considerable formalisation and mathematisation of knowledge, and do not yet fully know how to use it in practice, but its advantages from the point of view of management of soil processes and soil fertility as a whole are doubtless both theoretically and practically. Indeed, if to think about this definition of *natural soil* (S) characterizing it as a result (f) of integrated and simultaneous action of *living organisms* (o), *climate* (cl), *relief* (r) and *time* (t) on the *parent rock* (p), the role of functional external bonds having determining significance in our relationship to soil as one of the main sources of life at the Earth's surface becomes clear.

SOIL AS VERY COMPLEX STRUCTURAL SYSTEM

There is one more important aspect of the DOKUTCHAEV's soil definition in its present more elaborated form, which is also not fully appreciated and used yet by soil scientists. The modern genetical soil science proceeds from a concept of soil as very complex structural system, e.i. the system with endlessly great diversity of internal and external functional bonds, which has very complex hierarchic structural organization (ROZANOV, 1967, 1975). For a long time in soil science and particularly in agricultural practices the concept prevailed that, by acting upon any one factor (for example, either available water supply or available nitrogen or phosphorus stock) it is possible to manage the processes of soil fertility. Presently, such an approach is recognized as principally impermissible as it is not applicable in substance to very complex systems which do not permit changing of only one factor at a time, as these systems are so dynamic and internally connected that *a change of one factor becomes an immediate cause of changes of others*, sometimes very numerous factors.

A concept of *hierarchic levels of structural soil organization*, which has an important methodological significance, was developed on the basis of the above approach (ROZANOV, 1975 ; VORONIN, 1979). It was demonstrated that investigation of soil as a natural body requires distinguishing the hierarchic series of levels of structural organization of soil, each of which demands specific methods and approaches of study, control and management:

1° level of *atomic interactions;*
2° level of *molecular-ionic interactions;*
3° level of *elementary soil particles;*
4° level of *micro- and macro- aggregates*, soil new formations and inclusions;
5° level of *soil genetical horizons;*
6° level of *soil individuum* (soil profile, soil body, pedon);
7° level of *elementary soil area:*
8° level of the *soil cover.*

These concepts appeared as a basis for detailed studies of construction and structural organization of soil body (TARGULJAN *et al.*, 1974; KORNBLUM, 1974, 1975; KARPATCHEVSKI *et al.*, 1980), which revealed the need for principally new approaches to studies of soil constitution in a complex of micro-, meso- and macro-morphological analysis with the utilization of precise analytical instruments directly in the field.

These studies appeared as a realisation of the system hierarchic approach to soil investigation and clearly demonstrated the complex hierarchy of morphological elements in soils and corresponding to them soil-formation processes. The concept of soil *morphons* (horizontal, interhorizontal, extrahorizontal or ahorizontal) as complex or composite morphological elements and soil *morphems* as simple morphological elements was introduced (KORNBLUM, 1975). The genetical soil horizon appears in this hierarchic system of morphological elements as certain polymorphon (repetition of monotypic morphons) or heteropolymorphon (repetition of heterotypic morphons), representing the largest subsystem within the united genetical system of soil body.

The results of a study of derno-podzolic soil of Moscow region by a complex of methods at micro-, meso- and macro-levels of its organization, which were published by V. O. TARGULJAN and his colleagues (1974), represents *an example* of the new system-hierarchic integrated approach to soil investigation, which was followed in many cases since then. In this study the authors attempted to discover the main combination of separate processes, which constitute general macro-process of soil formation, to characterize their distribution by the horizons and to evaluate their role in the differentiation of soil profile. The following components were studied:

1° *total mass* (TM) in all horizons;
2° *intrapedal mass* (IPM) there, where it was distinguishable morphologically from cutans on ped surfaces and from the matter filling up the cracks;
3° *inter-crack mass* (ICM) for the horizons where the structure was weakly developed, but it was possible to separate the matter filling up the cracks from inter-crack matter;
4° *intra-crack mass* (INCM) of large cracks ;
5° substance of various physically separable *cutans and new formations.*

All these data furthered development of factually justified concept of genesis for the studied soil in connection with the history of post-glacial evolution of landscapes in this region. On this basis, a very important methodological conclusion was made concerning the relationship between soil properties and its genesis. It was shown that the soil, which is observed and studied "today", is not the adequate product of only present combination of factors of soil formation, of the present environment. The results of long and complicated evolution are reflected, "recorded" integrally in the soil profile.

Further development of this concept have lead to formulation of a principle according to which in any given soil there is a combination of conservative, stable features resulting from ancient, sometimes not acting any more processes, and modern, "alive" features which are being formed at present: "*soil-memory*" and "*soil-momentum*" (TARGULJAN, SOKOLOV, 1978). The "soil-memory" of TARGULJAN and SOKOLOV is not well known to soil scientists pedorelict, but those conservative, stable features of present-day soils (for example, granulometric and mineralogical differentiation of the profile into genetical horizons), which are formed in a long history of soil formation, inherited and included into the profile of present-day soil.

CONCEPT OF SOIL EVOLUTION

The above described concepts appeared to be as the further development and deepening of the concept of *historism of soil formation* (KOVDA, 1969). The long existing doctrine of contemporanity, according to which the present-day soils reflect in their constitution and features the complex of present-day factors of soil formation and are formed under its influence, was replaced by the concept of history of soil formation, the basic elements of which were already outlined by V. V. DOKUTCHAEV (1883). According to this concept, the present-day soils are not necessarily adequate to the present-day complex of factors of soil formation. On the contrary, the majority of world soils are the ancient soils, which have passed in their evolution a number of *stages of evolution* which proceeded under the conditions quite different from the existing and under the influence of another complexes of factors of soil formation. The present day factors of soil formation are responsible for the present regimes and processes going on in already formed soil profile which might have been developed under different conditions and regimes (KOVDA, 1973). Correspondingly, the well known formula "*factors—processes—properties*" is considered now in a historical aspect and with many notes. Purely descriptive formula "present factors—present processes—present properties" was replaced by a historical-dynamic formula "*factors in their historical development—processes in their historical development—present properties*". Such understanding of soil formation furthered substantial deepening of the DOKUTCHAEV's doctrine of factors of soil formation as a whole and allowed us to put the genetical analysis of soil formation onto a soil historical basis. Decades of serious scientific discussion were required to make this presently self evident concept generally recognized and adopted.

The historical approach to the analysis of soil and soil formation furthered broadening and deepening of the concept of soil and soil cover evolution which was originally formulated by the classics of Russian soil science.

The first scientific concepts of soil evolution we find in DOKUTCHAEV's works on Siberian (1882) and Russian (1883) chernozems. Indeed, these studies forced him to include time into the factors of soil formation. Already at the first steps of soil science an evolutionary principle was formulated, according to which the presently observed soil cover of the world should be considered only as one of the stages in its development, and separate soil forms with which we have to deal *at present* could present other forms of soil formation *in the past* and can undergo substantial transformation *in the future* (KOSSOVITCH, 1911). Later on, considerable factual material was accumulated by the Soviet soil scientists concerning the evolution of some soil types into the other and concerning the genetical bonds between different soils.

These evolutionary approaches and principles were utilized by V. A. KOVDA and his school in formulating a consistent evolutionary concept of soil formation and soil geography of the world, in which, although geochemically interconnected, but up to a considerable degree genetically independent evolutionary lines of soil formation of *three main morphostructures of the globe* have been considered: water-accumulative plains and lowlands, including glacial, fluvioglacial, alluvial and colluvial plains; denudation high plains and plateaux; mountain systems (KOVDA, 1965, 1973; KOVDA, ROZANOV, SAMOILOVA, 1968; KOVDA, DOBROVOLSKI, LOBOVA, ROZANOV, 1976 ; ROZANOV, 1977).

According to three main morphostructures of the land, three broad evolutionary lines of soil development have been distinguished: *hydromorphous*, *authomorphous* and *mountainous-erosion soil formation*, each with its own particularities and stages of soil evolution. Soil development in each of the evolutionary lines is considered on the background of geological processes of formation and development

TABLE 1

Evolution lines of soil formation (KOVDA, 1973; ROZANOV, 1977)

Evolution line	Stages of soil evolution	Formula of budget of substances in soil formation (1)	Geomorphic surfaces of land	Examples of main soil types at a given stage of evolution
1	2	3	4	5
Hydromorphous soil formation on water-accumulative plains	Hydroaccumulative soils	S=f(P+Ab+Am+Ag), t	marine coasts, deltas, estuaries, floodlands	mangrove, marsh and alluvial soils
	Hydromorphic soils	S=f(P+Ab+Ag), t	depressions and lowlands	swamp and semi-swamp soils, solonchaks
	Mesohydromorphic soils	S=f(P+Ab∓Ag), t	lowlands, slope teils, above-flood river terraces	meadow-chernozemic, meadow-chestnut, meadow-sierozemic soils
	Paleohydromorphic soils	S=f(P+Ab+Ag'-Ag), t	high river terraces, elevated lowlands	vertisols, solonetz, brunizems
	Proterohydromorphic soils	S=f(P+Ab+Ag''-Ag), t	weakly dissected elevated plains	chernozems, chestnut soils
	Neoauthomorphic soils	S=f(P'+Ab-Ag), t	highly dissected elevated plains	podzolic, pseudopodzolic soils
Authomorphous soil formation on denudation plains and plateaux	Primitive-authomorphic soils	S=f(P+Ab-Am-Ag), t	young denudation plains, highly dissected plateaux	lithosols, regosols
	Automorphic soils	S=f(P+Ab-Ag), t	denudation plains and plateaux	brownearths, brown aridic soils
	Paleoauthomorphic soils	S=f(P+Ab-Ag'-Ag), t	old denudation plains and plateaux	ferrallitic and allitic soils
Mountainous-erosion soil formation on mountain slopes	Mountainous primitive soils	S=f(P+Ab∓Am∓Ag), t	rocky young and uplifted mountains	lithosols
	Mountainous developed soils	S=f(P'+Ab∓Am∓Ag), t	high mountain systems	rankers, rendzinas, mountain-meadow soils, brownearths
	Mountainous ripe soils	S=f(P''+Ab∓Am∓Ag), t	old and denuded mountain systems	mountain red earths

(1) S = soil, P = parent rock, Ab = biological accumulation, Am = mechanical accumulation, Ag = present geochemical accumulation, Ag' = past geochemical accumulation, t = time of soil formation.

of the earth crust taking into account ancient and present tectonic, hypergenic and denudation processes, the processes of transformation and translocation of products of weathering and soil formation. A budget concept of soil formation was also utilized, as it was established that the main feature of soil formation development and evolution is the gradual change to *the budget of matter and energy* which is a result of interaction of little biological and large geological circulations of substances at the planet surface (see Table 1). The successive stages of evolution of the budget of substances in soil formation represent certain *quantitative-qualitative steps* of the process of evolution on the surface of the globe. The hydromorphous soil formation is usually replaced by neoauthomorphous in the processes of tectonic uplifts; at the same time, on the tectonically submerging territories a reversed change of stages of soil evolution may have place as well with the gradual growth of geochemical accumulation in previously eluviated soils (for example, salinization and carbonatization of ferralites).

Evolutionary-historical principles and concepts in this or that form play *the leading role in modern Soviet soil science*, constituting the basis for soil prognosis and amelioration.

SOIL AS A COMPONENT OF ECOSYSTEMS OF THE BIOSPHERE

Soil is presently considered by the Soviet soil scientists dialectically both as element of the soil cover, a specific global coating, *pedosphere*, and as a component of the *biosphere* (KOVDA, 1971, 1973, 1974, 1980). At the same time it is considered as a subsystem in natural and anthropogenic *ecosystems* (GILMANOV, 1977; BAZILEVITCH, 1979; FEDOROV, GILMANOV, 1980). Such three-dimentional approach to soil furthered particularly fruitful development of studies concerned with the problems of biological productivity of the global land (BAZILEVITCH, RODIN, 1965, 1967, 1970; KOVDA, 1966, 1971, 1974, 1977; BAZILEVITCH, 1979) and creating the manageable ecosystems, one of the main mechanisms of management of which is soil.

The consideration of soil as a component of the biosphere during recent decades appeared very productive, particularly in the studies of biological and geological circulations of substances and energy flows on biogeochemical cycles.

According to these concepts, the soil cover forms a specific biogeochemical coating at the Earth's surface which, being a component of the biosphere and a product of interaction between living matter and parent rocks, represents an area of concentration of organisms and energy assimilated by them, as well as the products of their metabolism and destruction (KOVDA, 1974). Organisms and soils function in the biosphere in united ecosystems supporting the existence of life itself at the Earth. The main functions of the biosphere in relation to soil are:

1° continuous process of *biogenic accumulation, transformation and redistribution of solar energy* coming onto the Earth;

2° support of the global *circulation of chemical elements*, particularly such biophyles as oxigen, hydrogen, carbon, nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, copper, cobalt, iodine, etc.

The most important result of these functional processes is the formation and accumulation of soil humus, the stock of biogenic carbon and energy in which are similar to that of the total biomass of the Earth's land.

Developing and furthering the ideas of V. I. VERNADSKI on the biosphere and its global functions, the soviet soil scientists, basing on the concept of soil cover as a component of the biosphere, have made a considerable input into the study and theoretical generalization of the newest problems of the biosphere at the time of the technical revolution and ecological crises. A concept of the main features and functions of the biosphere was furthered from these points of view, including:

1° *multitude of the components of the biosphere*, in myriads of terrestrial and aquatic ecosystems of which the assimilated solar energy, populations of authotrophic and heterotrophic organisms, soil cover, waters and earth crust form one of highest kinds of the global systems, living matter $\rightleftarrows$ environment, and the living matter, atmosphere, lithosphere, hydrosphere and pedosphere are the main segments of the biosphere, closely interconnected among each other by the flows of substance and energy;

2° *homeostaticity of the biosphere* or its selfregulation which conditions its certain stability, elasticity and resistance to external influences;

3° *stability energy flow and accumulation*, which conditions the stability of function of ecosystems and the biosphere as a whole;

4° *expanding reproduction of the biosphere* in the process of its historical evolution and growth of natural diversity of forms of life and ecosystems;

5° *biogeochemical circulation of substances;*

6° *heterogenousness of the biosphere in space and time* (KOVDA, 1980).

These concepts have lead to formulation of a doctrine of new complex system, biosphere $\rightleftarrows$ man. The study of anthropogenic impacts on the biosphere and its components, including the soil cover, constituted a basis for the understanding of functions of *anthropogenic ecosystems*, particularly *agroecosystems*, which support the existence and development of the mankind. At this basis, the main principles of management of the anthropogenic ecosystems have been formulated.

The soil cover is the most important link in mechanism of the biosphere and its product at the same time, which plays an immediate role in such functions of biosphere ecosystems as synthesis, transformations, destruction and mineralization of organic matters, accumulation of energy and its redistribution over the global surface, selective absorption and accumulation of chemical elements, support of biogeochemical circulation of substances which provides the stability of environment for organisms, including man.

During the last fourty years the soviet soil scientists (B. B. POLYNOV, N. P. REMESOV, V. A. KOVDA, S. V. ZONN, N. I. BASILEVITCH, E. M. SAMOILOVA, T. I. EVDOKIMOVA, K. M. SMIRNOVA, V. N. MINA, L. A. GRISHINA, M. A. GLASOVSKAJA, *et al.*) have accumulated great factual material on the *biological circulation of substances* in the biosphere ecosystems. The cycles of especially important biophyles and their changes under the impact of economic activity of man were investigated. These studies constituted the basis both for the understanding of mechanisms of natural ecosystems functioning and for the management of the anthropogenic ecosystems as well (EVDOKIMOVA *et al.*, 1976).

It was demonstrated that the *biological productivity* of the planet is based on the global land on normal and balanced functioning of organisms and soil cover in the biosphere and, first of all, on the historically developed cycles of substances and flows of energy. As far as man does not interfere with the biosphere, it functions as a *selfregulating system*, producing biomass, regulating composition and properties of soils, hydrosphere and atmosphere. Interference of man by way of agriculture, animal husbandry, forestry, water economy, construction, mining, pollution by wastes, by way of extraction and consumption of a part of biological production requires organised and scientifically justified management of the biosphere and its components (KOVDA, 1980). At the present level of knowledge and technology, out of all main components of the biosphere, *soil is the most easily manageable component* (soil treatment, fertilizers, ameliorations, regulation of soil regimes). Particularly through soils it is the most easy to provide general conditions of stability of the biosphere and its ecosystems, namely the expansion of flow of the anthropogenic energy and provision of the optimal conditions of plant growth. In relation to development of world agriculture these general principles have lead to the conclusion that the growth of its productivity and effectivity in the conditions of continuous demographic expansion requires additional capital investments of energy (in its different forms) into agriculture and growth of assimilation of solar energy by plants, from one side, and, from the other, realization of the following complex of diversified measures scientifically justified for each particular set of conditions: optimization of water and heat soil regimes for agricultural crops by methods of agrotechnics, amelioration, accumulation and preservation of water and heat; provision of plants with nitrogen through fertilizers and biological fixation of atmospheric nitrogen; maximalization of carbon dioxide content in the aboveground of fields by way of obligatory application of organic manures and wastes, increase of soil humus supply and activization of soil biological activity; provision of plants with calcium, phosphorus, potassium, magnesium, microelements (KOVDA, 1980).

Special study of productivity of *agroecosystems* on the basis of detailed investigations of biological circulation of substances (LEVIN, 1972, 1973, 1979) allowed to make an important methodological conclusion that for the scientific determination of plant requirements in nutrients it is necessary to assess their content *in the total biomass*, including surface crop residues and root systems, and not only their content in the extractable products. The same studies provided basic data for outlying the ways of increasing biological productivity of cultivated soils. These are the measures directed onto change of properties and growth of effective soil fertility in accordance with the requirements of cultivated plants, from one side, and the measures on the most complete utilization of soil fertility and solar energy, from the other. It was demonstrated that, besides the culturization of soils and increase of their fertility, the important factors of growth of soil productivity and the output of agricultural production are:

1° improvement of structure of ploughed lands with the utilization of most productive species and varieties of plants, taking into account natural conditions and economic requirements;

2° increasing biological productivity of plants in crop rotations on account of density of their stands and their regular distribution over the area;

3° utilization of soils and agroclimatological resources during the whole warm period of the year for obtaining additional organic production of intermediate crops.

MODELLING OF SOIL PROCESSES

Consideration of soil as a subsystem in complex natural and anthropogenic ecosystems have lead to development of *a new scientific branch* in modern soil science, mathematical modelling of soil regimes and corresponding processes.

One of the lines of this new branch is connected with *mathematical description* of the behaviour of these or those chemical elements in ecosystems and prognosis of their behaviour in certain controlled conditions. At the basis of this approach there is a study of biological circulation of chemical elements, which pass in the process of functioning of an ecosystem from one its components into another in form of different chemical substances. Certain parameters of migration and accumulation of elements are established by analytical methods. It was shown that the study of general features of circulation of substances much easies the models that are used, which take into account only the main substantial particularities of the processes of migration in ecosystem, which provides the possibility of application of formal apparatus of mathematics to the analysis of migration phenomena (PROKHOROV, GINSBURG, 1971).

The above approaches were utilized for the construction of a model of annual nitrogen cycle in grass ecosystems (RYZHOVA, 1978), which reflects adequately the natural situation.

In connection with development of irrigation in southern regions of the U.S.S.R. and due to the need for providing and continuous supporting their optimal water-salt regime and budget, particularly great attention was given recently to the modelling of soil water-salf regime (PACHEPSKI *et al.*, 1976, 1980). This modelling was based on the results received in soil science and in the theory of water amelioration. Data of observations and investigations conducted during soil and amelioration surveys were taken as a source of quantitative information for the modelling. The system analysis was taken as a methodological basis for the construction of complex models, and the developed modifications of concrete apparatus of the system analysis served as the basis for realization of integrated models in the computers.

These studies have lead to formulation of general principles/stages of construction of *integrated models of soil processes*: selection of determining processes; selection of a system of budget areas; selection and control of models of determining processes; selection and control of models of interactions between processes; realization of integrated model in the computer; organization of keeping and finding of initial information massifs; treatment of initial information and assessment of the accuracy of works of models; concrete calculations. The analysis of results is being made at each of the stages. The modelling is always an integrative process of solving direct and reverse problems, in which the solution of direct problem is really a prognostic calculation, while the solution of reverse problem provides an opportunity to correct initial information and to select optimal parameters for the factors governing soil processes (PACHEPSKI *et al.*, 1976). The water-salt prognosis on the basis of solving the direct problems can be solved not only for separate irrigated fields or irrigation systems, but for the large territorial units, as for example for the southern regions of the U.S.S.R. in connection with the transfer of part of the river flow of the northern rivers to the south. The solution of reverse problems provides accurate data for selecting optimal technical and economic parameters of irrigation systems under construction or reconstruction.

Finally, there were *attempts of mathematical modelling of more general processes of soil formation as a whole* (GILMANOV, 1977). The dynamics of soil temperature, soil moisture, soil air were described in a mathematical form (FEDOROV, GILMANOV, (1980).

Modelling of soil processes and of the behaviour of natural and anthropogenic ecosystems as a whole or their components makes only the first steps; however, the importance of these studies for the future development of soil science is doubtless. This branch of the science develops rather energetically, particularly so as the soil scientists work here not in an isolation, but in a close co-operation with biologists, geologists, hydrologists and other specialists as appropriate. Mathematization of soil science is quickly progressing, and the soil science itself is more and more transformed at the present stage of its development from the descriptive science into an experimental one.

ELEMENTARY SOIL PROCESSES AND PRESENT REGIMES OF SOIL FORMATION

Utilization of system analysis approach by modern soviet soil science have lead to development of new concepts of elementary soil processes, the first ideas in respect to which were initially introduced by S. A. ZAKHAROV, S. S. NEUSTRUEV and B. B. POLYNOV in early thirthies on the basis of the DOKUTCHAEV's doctrine of types of soil formation. S. S. NEUSTRUEV (1930) wrote that the soil formation process in not only non-homogeneous in different conditions, but it represents a complex phenomenon composed of elementary processes, separate physico-chemical phenomena: this or that degree and direction of decomposition of the mineral part and organic matter, aerobic or anaerobic character of decomposition, these or those new formations, energy and direction of leaching, solution and translocation, etc. Combinations of these elementary processes give endless number of soil individuals.

Recently, this concept was particularly developed by I. P. GERASIMOV (1960, 1973, 1975, 1980), who believes that the elementary soil processes might constitute the basis for genetical soil diagnostics and classification and the basis for further development of the theory of soil formation as a whole.

According to I. P. GERASIMOV (1975), the main criterion for determination of *the elementary soil process* (E.S.P.) and its distinction from other phenomena and processes occuring in nature is the point that *these processes constitute in their totality the phenomenon of soil formation*, occur only in soils and, under certain natural combinations with each other, determine their main features at the level of genetic soil types, i.e. first of all, construction of the profile and composition and ratio of the system of genetic horizons.

Thus, according to the above definition, each *genetic soil type* is characterized by a certain and only to this type belonging combinaison of E.S.P., although some E.S.P. may and must appear in different combination in various soil types. From the other hand, degree of development of E.S.P. combination belonging to a certain soil type, as well as addition of other E.S.P. to this main combination provide an opportunity for the subdivision of soil types into *subtypes*, *genera*, *species*.

There are grounds to believe that, on the basis of this concept, I. P. Gerasimov and its school will introduce some new theoretical generalizations in the nearest future, particularly in the area of *soil diagnostics* and *classification*. It is believed that this concept may become rather fruitful from the point of view of management of soil processes as well, as these processes determine evolution of soils and their fertility, particularly in connection with the concept of present soil regimes.

The study of *present soil regimes* (water, salt, acid-alkali, air, temperature, redox, etc.) was started by the Russian soil scientists long ago, actually at the end of last century and the beginning of present one : for example, classical works of Ismailski and Vysotski on the water regime of chernozems. However, particularly detailed and integrated studies were carried out during recent decades in connection with wide development of pilot projects in different regions of the country. A system of methods of soil studies in the dynamics was elaborated (Rode, 1971). Large factual material was obtained, and general scientific concept of soil regimes as heterochronous (annual, seasonal, daily) dynamics of general and specific processes of soil formation, was formulated.

Study of the dynamics of soil processes or regimes of soil formation has great methodological importance from two points of view. First, it gives direct initial material for modelling and soil management as a whole. Second, it gives factual basis for the theory of soil genesis and evolution, particularly from the point of view of consistence or, vice versa, inconsistence between present-day soil regimes and construction, composition and other features of present soil.

CONCLUSION

Unfortunately, the limits of an article do not provide an opportunity to give full and extensive characteristics of all diversity of various scientific schools and directions in modern soviet soil science. Such very interesting and promising scientific directions were not covered here as the energetics of soils and soil formation (works of V. R. Volobuev and his school), geochemical aspects of soil formation (works of B. B. Polynov's school—M. A. Glazovskaja, G. V. Dobrovolski, V. A. Kovda, A. A. Perelman and others), structure of soil cover (works of V. M. Fridland and his group), new approaches to soil classification (M. A. Glazovskaja, V. R. Volobuev, V. A. Kovda, B. G. Rozanov, I. A. Sokolov, V. M. Fridland, G. V. Dobrovolski), soil regioning (G. V. Dobrovolski), soil ecology (V. R. Volobuev, L. O. Karpatchevski and others), etc.

The main what characterises the soviet soil science today *is the diversity of scientific approaches and directions on the basis of united general methodology*, which we may certainly named by Dokutchaev and which is based on the materialistic dialectics. Speedy development of experimental works, introduction of complicated instrumental field and laboratory technics, utilization of methods and approaches of mathematics, introduction of methods and concept of system analysis are characteristic for the present stage of development of the soviet science. At every level soil is considered as very complex structural system, consisting of numerous hierarchic subsystems in the ecosystems of the biosphere. This new approach, which is *connected with the new social order to soil science and with the transition from the task of inventarization to the task of management*, seems to be very productive and corresponding to general level of development of modern science as a whole. It is important to mention in the conclusion that this new level of development of the soviet soil science appeared to be *a logical consequence and continuation of long historical development* of the science itself, the moving force of which always was the direction onto solving practical problems which were put onto the agenda by the socio-economic development of the country; *inseparable connection of the fundamental scientific studies with the solution of practical problems* is a characteristic feature of the soviet science as a whole, and soil science is not an exclusion in this respect.

As was rightly mentioned by G. V. Dobrovolski and D. S. Orlov (1974), the modern speedly development of the soviet soil science is *induced both by internal and external factors*. The internal factors are connected with the logic of development of the science itself on the basis of its fundamental studies within the framework of the adopted methodological concept. The external factors are connected with the requirements of solving large socio-economic problems of country development and, first of all, the problem of food and agricultural raw materials for the fullest satisfaction of ever growing needs of the growing population. If previously this problem was being solved mainly on account of the increment of arable lands, now the agricultural policy of the state is directed onto the most rational and effective utilization of the existing lands on the basis of complex mechanization of agriculture, chimization, amelioration of soils, growth of general culture of agriculture and land use, introduction of regional soil-conserving agricultural systems. Now problems of environmental nature have appeared in connection with the growth of anthropogenic impact on soils and soil cover. They are being studied and solved within *the general context of protection and improvement of the environment.* The new level of development of the soviet soil science is determined particularly by these new global problems, being at the same time reinforced by new degree of technical equipment of science at the stage of scientific and technological progress.

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