

Problems of degradation of soils and measures on reaching its neutral level

S. Baliuk,

Academician of the NAASU, Doctor of agricultural sciences

V. Medvedev,

Academician of the NAASU, Doctor of Biological Sciences

L. Vorotintseva

h.D. in Agricultural Sciences

V. Shymel,

Ph.D. in Agricultural Sciences

NSC "Institute for Soil Science and Agrochemistry named after O.N. Sokolovsky» (the NTC ISSAR)

The purpose. To assess degradation processes in soils of Ukraine and to develop measures on reproduction of their fertility for reaching neutral level of degradation. **Methods.** Monitoring probes, system, statistical, analysis and synthesis. **Results.** It is proved that one of the principal problems of land reserves both in Ukraine, and in the world is degradation of agricultural lands. They submit data on areas of extending and reasons causing degradation processes, and put forward measures of their preventing aimed at reproduction of fertility of soils for reaching neutral level of degradation. **Conclusions.** For reaching neutral level of degradation Ukraine should have the precise strategy of protection of soils. Methods are offered for formation of special foundation for protection of soils, prevention and spread of soils' degradation — new tax at the rate of 0,5% of normative money evaluation.

Key words: *degradation, soil covering, neutral level of degradation, fertility of soils, degradation processes, protection of soils.*

The problem formulation. Soil is a basic, self-sustainable component of the natural environment and the biosphere as a whole, being a limited, irreplaceable and hardly recoverable natural resource that performs such important functions as: (i) production of bio-mass and food; (ii) bio-ecological, bio-energetic, bio-geochemical, hydrological, gas-atmospheric, etc. in ecology, alongside (iii) socio- informational activities.

Up to date, issues of soils' role and significance, balanced use, management, protection, as well as combating degradation, have gained a global level [1, 2]. This fact is confirmed by adoption of UN Conventions (such as "Combating desertification", "Biodiversity conservation", "Mitigating the climate change"); "Agenda- XXI" (Rio de Janeiro, 1992); "Strategic Program for Protection of Soils 2010 - 2019"; the "Revised World Soil Charter", etc.

The specific feature of Ukrainian soil cover is its diversity (about 40 types and over 800 subtypes) and heterogeneity, alongside up to 10-15 mio ha widespread poor-productive, technogenically contaminated and degraded soil-sites.

Over 60% of the national land-resource structure consists of chernozem type soils characterized by (i) remarkable fertility-potential, (ii) significant reserves of humus and nutrients; (iii) favorable structure for plants and water regime; and (iv) high bio- activity as well.

Yet at the same time, these soils appeared vulnerable to degradation processes evolution caused by disbalanced land- use system dominating in agricultural industry that generally fails to provide positive results in issues of soil protection, nor high economic efficiency and ecological safety [3].

These phenomena are partly resultant from disturbance of environmentally balanced equilibrium between agri-lands, forests and water reservoirs, having affected the stability of agro-landscapes and increased anthropogenic burden upon the soil cover [4].

* According to the materials of the report at the Interdepartmental Meeting "Working out the ways of achieving a neutral level of land degradation in Ukraine and establishing the corresponding national tasks"

Soil degradation is a consequence of inefficient technologies and a result of poorly arranged inter-relations within the agrarian sector.

In this regard, the most relevant issues include enhanced dissemination of the data on Ukraine's soil cover and obtaining a novel knowledge on: (i) interactivities among naturally-inherent and anthropogenic soil-formation factors, (ii) productive and ecological functions of soils, and (iii) soil-resource capabilities.

Elaboration of forecast outlooks to evolution of degradation processes in soils (at various scenarios of climate change and economic activity) would enable adoption of sound management decisions on the rational and well-balanced land- use.

In Ukraine, land protection is one of main state- policy vectors and an important component of sustainable development hereof.

The purpose of research: to assess degrees of land- degradation processes in Ukraine, and to elaborate ways of soil- fertility recovery, in order to reach the neutral level of degradation.

Research methodology. The present-day soil-studies (including monitoring and systemic, statistical, analytical and synthetic approaches) are a methodological basis of scientific research.

Research results. Currently, one of major problems of the global Land Fund is degradation of agricultural lands [5], and hence, it is rather relevant to elaborate sustainable land management and soil protection measures in order to suspend the land- degradation.

On a global scale, various types of soil degradation have been covered: water erosion (23.7%), wind erosion (11.9%), chemical degradation (5.1%), physical impact (1.7%) - of the total area of agricultural land [6].

At the same time losses only from erosion make up 26 billion USD a year.

In Ukraine, the following types of degradation dominate in such total areas (mio ha) as: 13.3 and 6.0 - water and wind erosion, respectively; as well as 14 and 12.6 - chemical and physical degradation [7].

Such a situation confirms the a high probability of further decrease in arable lands area, thus reducing land resources for population of both the Ukraine and the whole world.

Up-to-date, three United Nations profile documents were adopted: the "UN Convention on the Biodiversity Protection", the "UN Convention on Combat against Desertification", the "UN Framework Convention on Climate Change", all being aimed at providing sustainable development all over the world.

Ukraine has acceded to all three Conventions, which fact is confirmed by the Cabinet of Ministers' approval of the Concept and National Actions Plan to combat the soil- degradation and land-desertification (CM Directives #1024-r (Oct. 2014) and #271-r (Mar. 2016).

The National Academy of Agrarian Sciences of Ukraine has duly prepared a schedule for implementing the National Actions Plan.

By adopting these documents, Ukraine has contributed to: (i) implementing the decisions of UN Conference "Rio+20" on Sustainable Development (2012), (ii) reaching the new goals of sustainable development up to 2030 (approved by the UN General Assembly, 2015); and (iii) implementing the "UN Convention on Combating the Desertification", all aimed at neutralizing the land- degradation all over the world.

The neutral level of land degradation (NLLD) is a terrestrial status where quantity and quality of land resources necessary to maintain ecosystem functions, services and food security remain stable or increase within certain time and space framework and ecosystems[8].

The NLLD objectives and tasks include:

- elaboration and implementation of sustainable land management policies aimed at minimization of current land degradation and prevention hereof in future;

- Recovery and re-naturalization of degraded and poor-productive lands.

Major goal of reaching the neutral level of land degradation includes: (i) identification of factors that cause desertification; (ii) elaboration of practical measures necessary to combat desertification and mitigate effects of the drought; (iii) improvement of conditions of affected agroecosystems and land use; (iv) integration into the world information systems via creation of soil information centers, databases, etc.

Degradation are natural and anthropogenic processes of natural properties' and soil regimes' deterioration resulting in sustained negative changes in their functions, reducing resistance and fertility [9].

Under such conditions, the intensity of soil- destruction processes exceeds the speed of soil-forming processes and soils' recovery.

Such soils whose ecological functions are irreversibly gone, and which for a certain time (at least 10-15 years, according to international experts) are characterized by poor yield/ harvests, should be considered as degraded.

Most often soils become degraded under conditions of excessive man- caused (mechanical, chemical, hydrotechnical, etc.) burden.

In authors' opinion, the list of baseline indicators for degraded land should be expanded with such as: land conditions, soil-productivity, carbon stock,- in order to obtain a more objective assessment of soil degradation.

The total area of degraded lands in Ukraine ranges from 6-8 to 10-15 mio ha [1].

Degradation phenomena evolve where degree of burden on soils exceeds their ability of self-regulation (i.e., capability to restore their natural properties independently, and without extra efforts).

According to State Standard 'DSTU 7874:2015' [9], soil-degradations feature 6 types and over 20 subtypes (Table 1).

Table 2 outlines inventory of degraded soils per types of degradation.

Degradation processes on arable lands may evolve by total, regional, localized and/or local- impact scenarios.

For most types of degradation, a set of criteria and indices has been elaborated to identify a degree of an actual process; and in certain cases, these shall be corrected or specified.

Statistical assessment of soil degradation types has shown that the most widespread cases are dehumidification, nutrients' content decrease, physical decay, erosion, pollution/ contamination, and so on.

Moreover, irrigation- ameliorated land- areas suffer from salinization, alkalization, waterlogging & marsh- formation, contamination, etc.

Table 1. Types and subtypes of soil degradation [9]

Type of Degradation	Degradation Subtype	Type of Degradation	Degradation Subtype
Mechanical	Water erosion	Physico-chemical	Acidification
	Deflation		Secondary salinization
	Mechanical disturbances		Decalcification
	Drifted debris		Reduction of oxidation-reducing potential and loss of buffer functions
Physical	Deterioration of physical properties in soil	Biological	Reduced biodiversity
	Perpetual changes in granulometric and aggregate composition		Reduced biological activity of soil
	Perpetual changes in water and thermal regime		Deterioration of sanitary conditions
Chemical	Deterioration of soil-humus conditions		Radiation
	Trophic depletion of the soil	Radioactive contamination	
	Salinity		
	Pollution/ contamination		

Table 2. Character of degradation processes distribution in soils of Ukraine [10]

Type of land degradation	% of arable land
Loss of humus and nutrients	43.0
Soil compaction	39.0
Soil-mudding (siltage) and soil cover crust- formation	38.0
Soil-cover water erosion	17.0
Acidification	14.0
Marsh- formation	14.0
Contamination with radionuclides	11.1
Deflation (loss of top soil layer)	11.0
Pollution with pesticides and organic dirt	9.3
Contamination with heavy metals	8.0
Salinization, alkalinization	4.1
Water erosion, formation of field gulleys	3.0
Side effect of water erosion (siltage of open reservoirs)	3.0
Deformation of earth's surface by the wind erosion	0.35
Decrease in the daily surface level	0.35
Aridization of soils	0.21

One of commonplace events of soil-degradation is its physical type that includes such processes as: (i) formation of soil-boulders across the total 4 mio ha; soil- dust storms (14 mio ha); soil-compaction (17 mio ha); productive moisture deficit during generative organs formation (21 mio ha), and soil-structure deterioration (14 mio ha) [7].

On such soils, plants poorly adapt to climate change, dry conditions and moisture deficiency.

Depending on the degree of degradation processes, crop yields can fall by 10-20% and even by 30-50%, while losses due only to shortage of the produce-output a year may amount to over UAH20 billion (*). [11].

(* NOTE: UAH is abbreviation of UKRAINIAN HRYVNIA (the national currency)

Along with these facts, the quality of agrarian produce deteriorates also, thus threatening with "hidden hunger" phenomenon.

Among problems of soil degradation, it is important to: (i) set up priorities, (ii) identify problematic areas, (iii) arrange for their systemic monitoring and, eventually, (iv) draft a plan of negative phenomena elimination.

In Ukraine, for instance, soil erosion and compaction are spread across a wide areal; yet, these processes were never given a proper research attention.

Calculations of monetary- economic losses due to land degradation are also a serious task that would automatically emphasize importance of this problem, with no need to declare it.

The causes of degradation processes' evolution and major unsolved yet soil resources' management-problems in Ukraine include:

- non-optimal inter-relations between land-sites and structure of arable fields;
- imperfectly substantiated Land Reform which has led to violations of agri-technologies and, as a consequence, resulted in downgrade of soils' fertility;

Underestimation of real threats from the development of degradation processes; societal misunderstanding of these problems, the lack of aspirations among farmers and agroholdings to maintain soil fertility;

- insufficient resource inputs (little dosage- rates of organic and mineral fertilizers and chemical ameliorants) and, as a result, the deficit balance of biogenic elements;
- poor legal normative provisions, and absense of effective tools to implement the land- protection laws;
- absence of objective prices per item of soil resources, alongside fair taxation; and lack of a relevant fund- assets necessary for maintenance of soils' fertility restoration;
- weak power of governmental management of land resources; lack of state, oblast and regional soils' protection programs;

- soil cover monitoring techniques not harmonized with European standards.

Ways of solving the problem of preventing soils' degradation and recovery of their fertility to reach the neutral level of degradation.

In view of the role and significance of the soil cover, Ukraine is merely obliged to possess a distinctly-defined strategy of soil protection, prevention and control of land degradation that would include: (i) an effective functioning of soil protection programs and laws; (ii) strict control over their implementation; (iii) monitoring; (iv) mandatory regulation of anthropogenic burden; (v) responsibilities & liabilities of authority decision-makers and all land users; (vi) observance of recommended measures and (vii) implementation of innovative soil-protection technologies.

This strategy is aimed at creation of conditions for: well-balanced use of soil resources; prevention of soils' degradation, and ensuring its neutral level.

In order to cope with this task, it is imperative to arrange for legislative and regulatory basis- support in field of soil protection.

The following regulatory framework needs to be implemented:

- Draft Law of Ukraine "On Amendments to Certain Legislative Acts Concerning Improvement of Soil Protection Mechanisms and Economic Stimulation of Soil Fertility Restoration" that would: (i) define legal, economic, ecological and organizational tools for the use and conservation of soils, protection and recovery of soil fertility; (ii) establish basic principles of the State Policies in this area, as well as requirements for maintaining the soil cover quality and protecting it from negative natural and man-inflicted impacts;

- the draft National Soil Protection Program, whereon regional and district programs should be verbalized using the funds of governmental, regional and local budgets;

- National Actions Plan to combat land degradation and desertification, formulated on basis of the profile Concept adopted by the Cabinet of Ministers of Ukraine;

- Draft State Program for Soil- Surveys and the Concept of the Environmental Monitoring System Reform;

- The Concept and recommendations on achievement of the degradation- neutral level (*these documents being now underway in preparation*);

- The program of ensuring the neutral level of land degradation (using the UNCCD(*) system of indicators) includes: (i) a remote study of soil- and vegetation- covers, and soils' productivity and (ii) an experimental research of the organic carbon dynamics.

(*) NOTE: UNCCD is the United Nations Convention to Combat Desertification

It is attractive with its relative data informativity and seems reliable to assess actual status of soil degradation, judging by degree of soil- humus- losses and processes linked herewith.

Regretfully however, this Convention does not envisage the entire diversity of soil degradation processes in Ukraine.

In part, it concerns such processes as man-caused contamination; physical degradation; irrigation-inflicted soils' transformations, drainage etc. that eventually have become widespread events [7].

In authors' view, assessing degradation by index of productivity is not entirely accurate, since it often results from only advanced agro- technologies, not soil- fertility.

In recent years, technologically advanced equipment of rich agricultural holdings has been masking unintentionally certain "dark sides" (even among the most fertile chernozems), for example: (i) deficit of moisture (70% of arable land) and available phosphorus, in addition to (ii) numerous evidence of physical soils' degradation.

A systematic monitoring on stationary test-trial sites using a wide range of relevant indicators may become a most reliable, validated and acceptable methodological basis for assessment of soil degradation in Ukraine [6].

It would be expedient to supplement such systematic studies with non-stop control of nutrients' up- and down- migration in crops under stationary and lysimetric test-site conditions.

By the way in the USA, monitoring-observations have been made since 1972 upon ~2000 such stationary platforms; or 192 test- sites since early 1990-ies in Germany; while in China, their number is constantly increasing [6].

Normative-methodological, technological, informational, financial support and use of international experience of environmental protection activities in land- use can be considered as major components of the soil resources' management and protection system.

Regulatory and methodological fundamentals for soil protection. Over 300 normatives (including those for "Quality and protection of soils" sector and "Soil degradation" sector) have been prepared and implemented, of which 160 documents were harmonized with international and European standards.

To this end, coordinated efforts from scientific institutions to elaborate uniformly harmonized soil-degradation normative documents are required, because many degradation types have no agreed assessments as yet.

Technological provisions for soil protection. For the maximum effect, the present-day agro-technologies should be adapted to soil and climatic conditions.

Authors have identified such priorities (that could be based on up-to-date agricultural systems) as: (i) optimizing the organic matter content in soil; (ii) monitoring the mobile forms of nutrients; (iii) establishing a deficit- free balance of humus and nutrients in soils; (iv) protecting the soils from erosion; (v) recovering acidic and saline soils; (vi) protecting soils from contamination, compaction and waterlogging; (vii) eliminating the moisture deficit in soil.

A relevant pilot project can be hosted and implemented in Kharkiv region (Ukraine) where adequate informational and manpower resources are available.

Financial support to soil protection. Expenditures on implementation of basic soil protection activities amount to 41 - 48 billions UAH a year, including those from governmental and local budgets and funds of land users as well [11].

The forecast- estimated annual economic effect from increasing the crop- yield can make up 3.6 to 4.0 billion UAH, while ecological and economic indices of these activities can amount to 25 - 28 billion UAH.

It should be admitted that investments' flow into matters of Ukrainian soils rational use and protection is rather limited.

Several definite ways to establish a fund (in support to soil protection, stop and combat degradation), via imposition of a target fee (0.5% from the total normative monetary value) and some others were proposed, which in aggregate could provide an income of ~4 billion UAH a year [11].

Issues of economic damage and the search for sources of funding are extremely actual.

An important aspect is employment of the environmental conservation international experience in sphere of land- use activities.

Many bright examples of progressive land use practices have been accumulated in the world, deserving so much to be studied and used to maximum.

To elaborate an effective soil protection strategy, it is necessary to activize international activities against the degradation.

Up-to-date, the present-day worlds' soil protection strategies take their start from the following principles:

- independence from land- ownership forms;
- soil monitoring per world-universal techniques;
- territorial zoning with discretion of problematic soil-sites under "**hot spot**" labels (warning of their unfavorable properties);
- introduction of agricultural (minimal, conservative, zero, supportive, precise, organic, etc.) soil-protecting technologies;
- financial aid/subsidies (up to €125/ha) to farmers who really support and adhere to soil-protecting technologies;
- legislative soil protection acts, directives, declarations, charters.

Currently, the O.N. Sokolovsky Institute is busy implementing certain projects of (i) creating a Soil-Information Hub; (ii) completing a Soil Organic Carbon Database; (iii) assessing ecosystem services of salinated soils; (iv) creating a Headquarter of Chernozem Soils; (v) preparing the Atlas of European Soils.

The source of soil information is monitoring. The major features of European soil monitoring include:

- independence from ministerial supervision;
- open access for population to fresh information on status of soils;

- a simple 2-link structure (Regional Laboratory ↔ Research Center);
- a wide list of soil-related indicators;
- special status of stationary monitoring-observation sites;
- periodically-scheduled certification of analytical laboratories, instrumentation and personnel;
- a strict personnel liability for the accuracy of the information received;
- a uniform methodology of work implementation, harmonized with all other environmental links.

In order to harmonize the agrochemical certification strategy with the land- monitoring practice (on example of advanced European experience gained by France, Germany, Sweden), it is necessary to:

- establish a network of stationary monitoring-observation stations whose functional regularity shall depend on variability of natural and economic conditions;
- substantially expand the range of analytical work procedures (i.e., identify: (i) gross forms of certain elements; (ii) organic & inorganic pollutants; (iii) individual physical, chemical and biological indicators of soils).

Of particular importance are indicators of soil-erosion and compaction being never been taken in account or measured before, despite now- threatening spread of these processes;

- cover all categories of the Ukraine land cover with monitoring-observation, instead of surveying only agricultural fields as practised before now;
- create databases and information systems (ranged from regional to national) taking into account present-day requirements.

Thus, in order to increase the soil fertility and reach the neutral level of degradation, the following measures are necessary:

- elaboration of proposals for drafts of legislative and normative-regulatory acts on soil monitoring procedures;
- preparation of the Concept and recommendations to ensure the neutral level of soil degradation;
- establishing a Soil Information Center and sending proposals to FAO to provide financial support to the soil-monitoring and protection services;
- reanimation of stationary field test-trials aimed at study of soil processes, regimes, and vectors of soil-evolution due to predicted climate change;
- adaptation of farming technologies.

Authors have prepared the first edition of the Concept titled "Measures to reach the neutral level of land degradation in Ukraine".

Implementation of the National Plan of Actions to combat soil degradation and desertification (which consists of 2 stages) shall be considered as the first priority task.

Stage- 1: 2017 to 2020 span:

- creating legal- normative and technical- normative platforms;
- elaborating zonal, regional and oblast programs for reaching the neutral level of land degradation;
- ensuring minimization of soil degradation;
- initiating the soil survey policy;
- practising the soil mapping and establishing a Soil - Information Center;
- maintaing the soil status control;
- introducing the resource-saving technologies.

Stage- 2: 2021 to 2030 span:

- (i) Upgrading the legal- normative and technical- normative base; (ii) ensuring neutral level of soil degradation; (iii) conducting the soil-agrochemical surveys; (iv) restoration of degraded and non-productive lands, (v) re-naturalization of degraded ecosystems; (vi) stimulation of the soil-recovery and soil fertility protection efforts.

Conclusions.

Today, one of the main problems of the Global Land Fund is the agricultural land degradation.

The total area of degraded lands in Ukraine ranges from 6-8 to 10-15 mio ha.

Depending on degree of degradation processes, yielding capacity of agricultural crops may decrease by 10-20% and 30-50%, while losses only due to shortfall in produce harvested can make up over 20 billion UAH a year.

In order to solve the problem of soil fertility-recovery while achieving the neutral level of soil degradation, Ukraine must have a clear strategy of soil- protection alongside prevention and combat land degradation that would empower: (i) an effective functioning of relevant programs and laws; (ii) strict implementation-control hereof; (iii) soil-monitoring activities; (iv) mandatory regulation of anthropogenic burden constraints; (v) administrative responsibilities of authority agencies and land users; (vi) observance of recommended techniques and (vii) promotion of innovative soil- protection technologies.

In order to increase soil fertility and reach the neutral level of degradation, the following measures are necessary to: (i) elaborate proposals for draft legislative and regulatory acts on soil monitoring, (ii) formulate the Concept and recommendations aimed at the neutral level of soil degradation, (iii) establish a soil information center, (iv) give a new life to now-lost strategies of stationary field experiments at studies for soil processes, regimes, and evolution- trends in view of predicted climate change; (v) adapt agricultural technologies to present-day realities.

Realization of the National Action Plan of the Soil Degradation Control (including a list of appropriate measures up to 2030) would definitely help resolving this issue.

Bibliography

1. S.A. Balyuk, V.V. Medvedev, O.G. Tarariko et al. // On the Status of Soil Fertility in Ukraine // National report // Kyiv, 2010. - 111 pps.
2. Revised World Charter of Soils// FAO, 2015 - 8 pps. <http://www.fao.org/3/b-i4965r.pdf>
3. S.A. Balyuk, B.S. Nosco, E.V. Skewer// Present-day problems of biological degradation of chernozems and ways of preserving their fertility// Bulletin of Agrarian Science. - No. 1. - Kyiv, 2016. - 11-17 pps.
4. SA Balyuk, VV Medvedev // Strategy of balanced use, recovery and management of soil resources of Ukraine// - Kyiv, Agrarian Science, 2012. - 239 pps.
5. The state of world land and water resources for food production and agriculture. Managing Systems at Risk. - FAO, 2012. - 285 pps.
6. S.A. Balyuk, V.V. Medvedev //Concept of organization and functioning of soil monitoring in Ukraine in view of European experience// Kharkiv, "Smugasta" typography, 2015. - 45 pps.
7. A.S. Zarishnyak, S.A. Balyuk, V.V. Medvedev et al.// Scientific provision of management of soil resources in the context of European integration processes.// Scientific report - Kharkiv, 2016. - 44 pps.
8. Proceedings of the 12th Conference for the UN Convention to Combat Desertification//<http://www.menr.gov.ua/press-center/news/150-news28/4301-vidbulasia-12-konferentsiia-storin-konventsena-on-pro-borotbu-z-upusteliuvanniam>.
9. DSTU 7874:2015 (National Standard of Ukraine): 'Soil protection. Degradation'// [Effective from 06/25/2015]. - Kyiv, State Enterprise "UkrNDNC", 2016.- 9 pps.
10. V.V. Medvedev// Scientific approaches to assessment of the quality of soils across the regions of Ukraine)// Collected proceedings titled "Countries and Regions on the Way to Balanced Development". - Kyiv, 2003. - P. 62-64 pps.
11. A.V. Kucher, O.V. Anisimova, I.V. Kazakova, et al.// Economic support to recovery of soil fertility// Kharkiv, "Smugasta typography", 2015. - 112 pps.