

Ukrainian chernozems as a factor in global food security and resilience of agriculture to climate change

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Abstract

The objective of this report was to demonstrate the role of Ukrainian chernozems as a factor in global food security and sustainability of agricultural production to climate change. We used such methods: abstract and logical, monographic, expertise, computational and analytical. The leading role of Ukraine in the formation of global food security is discussed. The report shows the results of preliminary assessment of the Ukrainian soils' contribution into the global soil problem of carbon sequestration. The scale of organic carbon losses due to inefficient use of land is analyzed. The report indicates perspective directions of organic carbon reproduction in the chernozems of Ukraine to support/increase its reserves and provide neutral land degradation. Proposals for future Plans of Actions to increase the capacity to manage reproduction of organic carbon in chernozems of Ukraine are included.

Key words: chernozems, soil organic carbon, humus, food security, land degradation neutrality.

General information on land resources and soil cover of Ukraine

The total area of Ukraine is 60.35 mln.ha, area of lands - 57.93 mln.ha. Land Fund of Ukraine is divided as follows [1]: agricultural lands - 42.74 mln.ha (arable lands - 32.53; hayfields and pastures - 7.86; fallow lands - 0.25; gardens - 0.89); forest lands - 10.62; wetlands - 0.98; built-up lands - 2.54 mln.ha.

Soil cover of Ukraine is very diverse and has up to 1000 kinds of soil. On 2/3 it consists of chernozems soils (about 25.3 ml.ha). At the same time chernozems ordinary cover an area of 10.5 mln.ha, typical - 5.8, southern - 3.6, podzolized - 3.4 and chernozem-meadow soils - 2.0 mln.ha. Also, significant areas are occupied by fertile gray forest soils (4.3 mln.ha), the sod-podzolic soils (up to 3.9 mln.ha), chestnut soils (1.4 mln.ha), brown soils (1.1 mln.ha) and meadow -marsh soils (about 1 mln.ha).

Contribution of Ukrainian soils in the global food security

According to preliminary data, in 2016 Ukraine harvested a record yield of grain and sugar beet. Thus, production of grain and leguminous crops is almost 66 mln.t at average yield is 4.61 t/ha; gross harvest of sugar beet amounted to 13.9 mln.t with the yield of 48.2 t/ha. In recent years Ukraine is confidently among ten largest world producers of major products in agrofood sector, both in terms of gross production and the volume of exports. Thus, in 2014 on the production of sunflower and sunflower oil Ukraine held the 1st place in the world, barley – 3rd; nuts – 4th, maize and honey - on 5th; soy - on 8th and wheat – 9th place. On export of sunflower oil Ukraine occupied 1st place; grain and nuts – 2nd; maize and rapeseed - 3rd; barley – 4th; wheat – 6th place in the world. In 2015/2016 marketing year, according to the Ministry of Agrarian Policy and Food, Ukraine exported 39.4 mln.t of grain (<https://delo.ua/business/avtory-rekorda-top-10-krupnejshih-eksporterov-zerna-iz-ukrainy->

319734/). These data indicate that Ukraine plays a strategic role in global food market and ensuring global food security.

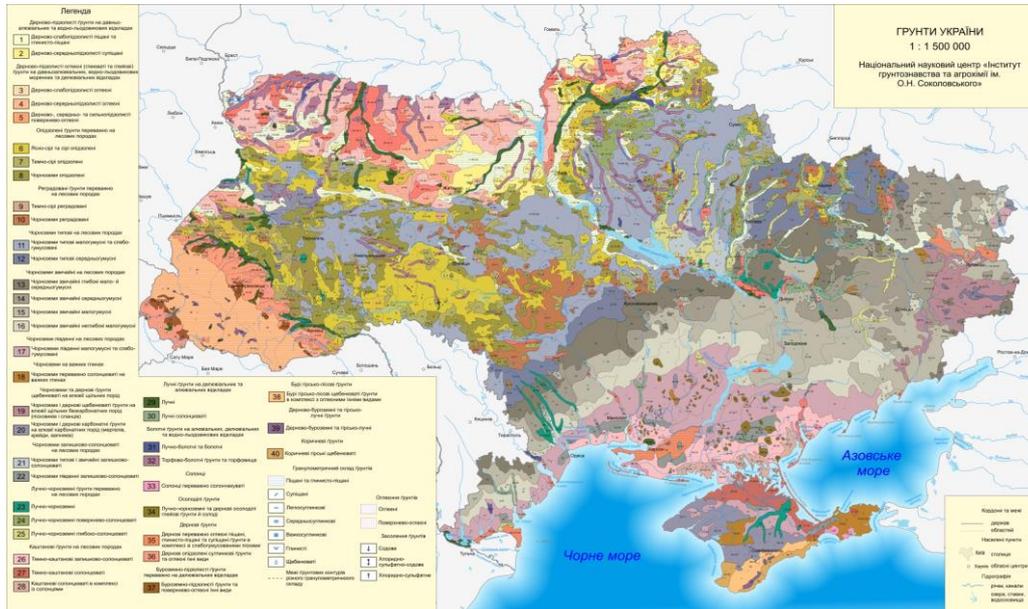


Fig. 1: Soil map of Ukraine 1 : 1 500 000 (NSC ISSAR, 2016)

Preliminary assessment of Ukrainian soils contribution into global carbon sequestration

Soils of Ukraine are characterized, in general, by average (2-3%) and high (3-4%) humus content in arable layer (map on Fig.2). Soil area with this content is 16.4 mil.ha, or about half of the arable land. Depth of Ukrainian soil profiles varies very widely and for chernozem soils depending on geographical, climatic and other factors is between 50 and 150 cm [2]. Stocks of humus (SOC) in the main Ukrainian soils also vary widely: humus 100-720 t/ha, SOC 60-420 t/ha (Tab.1).

According to preliminary expert estimates of NSC ISSAR researchers total SOC stocks in Ukrainian soils are about 7 Gt. This compares with 1/3 of SOC in agricultural soils of EU, which are estimated about 18 Gt in 0-30 cm layer [3].

Potential of SOC stock increasing by using the best agricultural technologies and balanced application of fertilizers is quite high. According to expert estimates it can reach 0.1-0.3% for the layer 0-30cm in medium term (5-10 years).

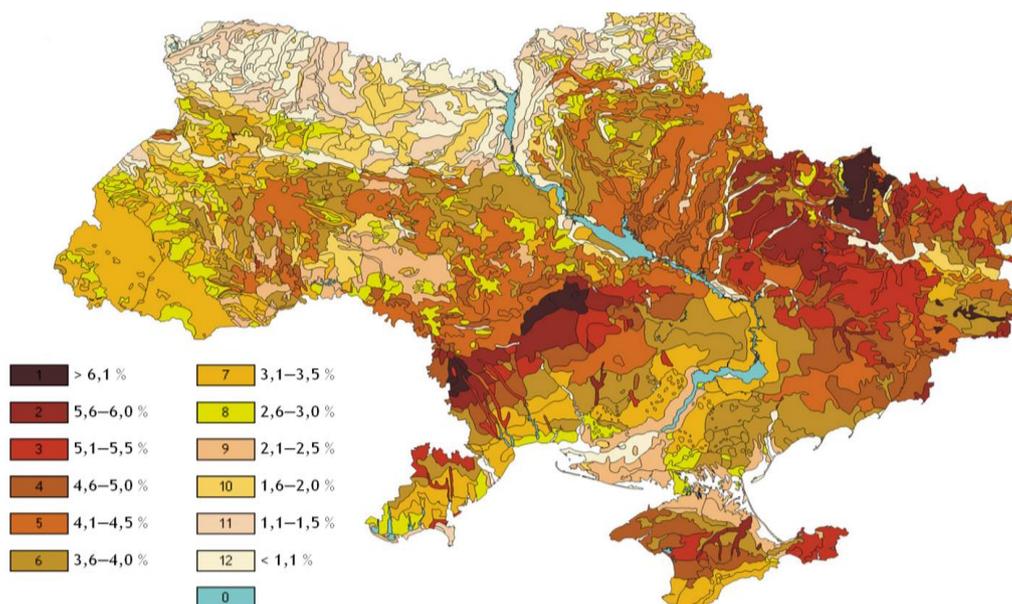


Fig. 2: Humus content in the arable layer of soils of Ukraine (National Atlas of Ukraine, 2007)

Table 1: Stocks of humus and SOC in Ukrainian soils

Type of soil	Humus content in arable layer, %	Humus in profile, t/ha	SOC in profile, t/ha
Chernozems ordinary	3.5-5.7	200-550	116-319
Chernozems typical	2.5-6.0	300-600	174-348
Chernozems southern	3.0-3.5	200-250	116-145
Chernozems podzolized	2.6-4.5	220-350	128-203
Chernozem-meadow soils	3.0-7.2	360-720	209-418
Gray forest soils	1.3-3.5	100-230	58-133
Sod-podzolic soils	2.0-3.7	150-280	87-162

Information for SOC mapping

Sources of information about content of humus and SOC on agricultural lands that are currently used for the preparation of SOC Ukrainian maps are:

- Database "Soil Properties of Ukraine", developed by the NSC ISSAR;
- Materials of large-scale soil survey 1957-1961 years;
- Materials of agrochemical certification of agricultural lands;
- Database of ecological and agro-reclamation state of ameliorated soils, developed by the Institute;
- Data of research institutions of various Ministries and Departments and universities;
- Data of stationary field experiments listed in State Register of Ukraine.

SOC data for non-agricultural lands (about 18 mln.ha) are scattered in dozens of organizations from different Ministries.

The Institute carries out all-Ukrainian geo-oriented Database "Soil properties of Ukraine", which by 31.01.2017 contained about 2,000 points on the SOC content. Database replenishment is going on by information available in a variety of "soil" organizations of Ukraine (academic institutions, universities, etc.).

First edition of the National Digital Raster SOC Map of Ukraine for 0-30cm layer with grid 1x1km must be prepared in April 2017 with FAO support.

Loss of humus because of irrational use of land

In Ukraine, since the days of V.V.Dokuchaev there have been conducted numerous researches of organic matter dynamics in soils. They showed that average loss of humus for nearly 130-year period reached 22% in forest-steppe, 19.5% - in the steppe and about 19% - in Polissya regions of Ukraine. Annual humus loss is 550-600 kg/ha and more [4, 5].

According to stationary tests, a long-term plowing and cultivation of soil without adequate fertilizer application leads to significant losses of humus (Table 2) on all analyzed depths - up to 60 cm.

Table 2: Humus content (%) in virgin (non-turf) and plowed chernozems

Depth, cm	Chernozems			
	typical, virgin land	typical, arable land	ordinary, deposit land	ordinary, arable land
0-10	7.76	4.58	4.61	4.25
10-20	6.08	4.55	4.35	4.20
20-30	5.05	4.51	4.28	4.12
30-40	4.79	4.29	3.74	3.48
40-50	4.05	3.85	2.80	2.61
50-60	3.82	3.60	2.65	2.49

The highest humus loss occurred in the 60-80-ies of last century due to increase of sugar beet and maize share in crop rotations. In the following years, level of annual application of organic fertilizers reached 8.4 t/ha and 170 kg/ha of mineral a.m., therefore equilibrium balances of humus and nutrients were reached. Afterwards, fertilization subsequently reduced and the humus balance became negative. In recent years, application of mineral fertilizers increased to 75 kg/ha, but there is no perceptible shift for organic fertilizer. NSC ISSAR research as described in [6] shows that humus loss occurs at 43% of arable land with a speed of up to 620 kg/ha per year (SOC loss 360 kg/ha*year) depending on rotation structure, tillage and standards of organic fertilizers [4].

Decrease of humus content is mainly due to following factors [6]: high level of plowing (56% of land area); catastrophic reduction in application of organic fertilizers (last 10 years less than 1.0 t/ha is applied instead of recommended 8-14); unbalanced use of mineral fertilizers; violation of cropping patterns; monoculture cultivation, reducing area of perennial grasses and legumes; high intensity of tillage.

Measuring, monitoring and reporting on SOC

Basic method of humus measuring is a modified method by I.V.Tyurin, which is standardized in Ukraine and used in all analytical laboratories.

Today, there is no specialized system of SOC monitoring in Ukraine. However, in Ukraine for more than 50 years agrochemical survey of agricultural land is carried out once every five years according to the method developed by NSC ISSAR. For each field 20 soil indicators are defined, including data on averaged humus content.

Only in the ninth round of 2006-2010, 26 mln.ha of agricultural lands were surveyed which included taking of about 2.7 mln. topsoil samples and preparing more than 450 thousand of agrochemical passports for individual fields [7]. Field passports as legal documents were made for land users and land owners with recommendations how to use and improve soil cover.

SOC management at national level

State of legislative provision of issues on soils protection in Ukraine in recent years has improved with the introduction of the Land Code of Ukraine, Laws of Ukraine "On Land Protection" and "On state control over land use and protection". According to these documents, Government has committed to organize and regulate the use, control and protection of soils.

Ukraine as a Party of UNCCD was invited to formulate voluntary targets to achieve Land Degradation

Neutrality (LDN) in accordance with specific national circumstances and development priorities. Therefore, in accordance with p.206 of Outcome Document of UN Conference on Sustainable Development "Rio + 20" and sustainable development goal 15.3 as set out in UN General Assembly documents from 09.25.2015 №70/1, Cabinet of Ministers of Ukraine adopted National Action Plan to Combat Land Degradation and Desertification 30.03.2016 p. [8]. It provides activities related to the provision of LDN and SOC stock enhancement, in particular:

- development of the law draft "On the protection and preservation of soil fertility";
- conducting surveys of land in Ukraine;
- conducting soil-agrochemical survey and agrochemical certification of agricultural land;
- development of technologies for balanced use, protection and restoration of land and soil, prevention of their degradation. Creating an open database of soil conservation technologies and best practices;
- improvement of land and soil monitoring system.

It is taken into account that according to decision 15/COP 12, one of the three indicators for assessment of the processes of land degradation is "trend in carbon stocks above and below soil," as a metric it is adopted SOC stock in soil.

Unfortunately, funding sources for the implementation of this ambitious Plan are not identified today, therefore the Ministry of Ecology and Natural Resources of Ukraine expressed interest to join to the Land Degradation Neutrality Target Setting Programme (LDN TSP) which has been launched by the Secretariat and the Global Mechanism of the UNCCD with support of several bilateral and multilateral partners to assist Country - Parties to the Convention in implementing decision 3/COP12.

Scientific support of SOC management in Ukrainian chernozems

The National Academy of Agrarian Sciences of Ukraine at the expense of state funding carries out with a five-year cycle the research programs on Ukrainian soil conservation and improvement of soil fertility. Currently, NSC ISSAR implements National Research Program for 2016-2020 "Soil resources: Forecast of Development, Sustainable Use and Management". Most of 56 projects of this program in some way aim at improving the fertility of Ukrainian soils, that is, in fact, to maintain and increase SOC stocks. Unfortunately, this Program has a very limited government funding (about 0.320 mln.dollars in 2016).

Implementation of the Program is attended by about 300 researchers from 14 academic institutions and 8 universities of Ukraine.

The studies found a negative impact of dehumification on properties and processes in plowed soils: deterioration of chernozems trophic level; aridization of soil profile by strengthening the processes of physical degradation and deterioration of water regime; strengthening preference of downward water flow due to increase cloddiness and fracturing soil; mosaic abiotization of soils due to the increasing density of individual units; deterioration of water resistance of chernozems and increasing of erosion; strengthening of spatial heterogeneity of soil on field; worsening morphological, physiological, soil and productive indicators of plant root systems; weakening the turf soil. All factors lead to lower crop yields.

We studied the ways of reproduction of humus in current Ukrainian crisis conditions and prepared recommendations for the reduction of row crops share in rotations; use of optimal doses and technologies of mineral and organic-mineral fertilizers; application of technologies of minimum and zero tillage; application of both organic fertilizer plant residues and by-products of crops; growing green manure with subsequent plowing; improved utilization of manure and other organic waste as fertilizer source of SOC accumulation in soil.

NSC ISSAR proposals in Action Plans to increase SOC management capacity on chernozems

International projects and programs:

- Creation of International Network of Centers for chernozems protection with the participation of all interested countries;
- International projects on soil carbon monitoring, dissemination of technologies for SOC improving, on creation and testing of economic incentives for farmers to improve the systems of organic matter in soil;
- Implementation in Ukraine the International Pilot Project for low-cost soil carbon monitoring system on chernozems using spectrometric equipment and technologies of Dutch company SoilCares;
- Organization of international training seminars for studying of SOC monitoring technologies, for example, to study the Ukrainian experience in organizing regular agrochemical survey (certification) of fields;
- Extension of EU project LUCAS on topsoil survey on all European countries, including Ukraine.

National projects with foreign financial and technical support:

- Development of National SOC map in accordance with GSP specifications (carried out with FAO support);
- Creation in Ukraine the National soil-information system; identification of soil information gaps and conducting soil surveys in problem areas;
- Demonstration and dissemination of technologies to improve the humus content in Ukrainian chernozems and reducing of soil degradation;
- SOC loss assessment because of soil sealing in Ukraine;
- Establishment of a all-Ukrainian state system of soil cover monitoring, including SOC indicators;
- Development of theoretical and practical models of economic mechanisms (incentives) to SOC reproduction in agriculture, determine methods of state financial support for SOC reproduction.

References

1. National Report on the State of Environment in Ukraine in 2013. Ministry of Ecology and Natural Resources of Ukraine. Kyiv, 2015.
2. National Report on the State of Soil Fertility of Ukraine / Ed. S.A.Baliuk, V.V.Medvedev, O.H.Tararyko [etc.]. - K.: LLC «VIC-PRINT», 2010. - 111p.
3. Pan-European SOC stock of agricultural soils. European Commission Joint Research Centre, 2013.
4. The strategy of sustainable use, restoration and management of soil resources of Ukraine. S.A. Baliuk, V.V. Medvedev (scientific editors). Kyiv, Agricultural Science, 2012, 240 p.
5. Medvedev V.V. et al. Soil Heterogeneity and Precision Farming. Part 2: The results of research. Kharkiv: Urban typography, 2009. 260 p.
6. Oldeman L. R. World Map of the Status of the human-Induced Soil Degradation (GLASOD). An Explanatory Note / L. R. Oldeman, R. T. A. Hakkeling, W. G. Sombroek // International Soil Reference and Information Centre. Wageningen. – 1991.
7. Periodic report on the state of soil on agricultural land in Ukraine on the results of the 9th round (2006-2010) of agrochemical survey of land. Institute of Soil Protection of Ukraine, 2015, 118 p.
8. National Action Plan to combat land degradation and desertification. Approved by the Cabinet of Ministers of Ukraine dated March 30, 2016. №271-p.