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INDICATORS OF SUSTAINABLE DEVELOPMENT OF SAFETY LAND USE AND ASSESSMENT OF DEGRADATION PROCESSES DEVELOPMENT OF SOIL COVER USING GIS MODELS

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Abstract. *The article describes some of the UN-adopted indicators of sustainable development of land use safety associated with the development of soil degradation processes, approaches to assessing the development of soil degradation using mathematical modeling tools, namely geoinformation models.*

Indicator 15.3.1 of sustainable development goals reflects the ratio of the area of degraded land to the total land area of the assessed area, and degradation is considered as an integral indicator of such parameters as land productivity, soil organic matter content and type of land use. It is established that when using remote sensing data obtained from open sources, which serve as a basis for calculating land degradation indices by the Trends.Earth tool via QGIS software, it is possible to establish such changes at the administrative level (map scale 1: 100000) and spatio-temporal analysis of such changes.

At the same time, it is difficult to ensure higher spatial resolution, which would allow the analysis at the level of an individual farm or an enterprise. This is due to the spatial resolution of the data that form the basis for such a calculation. In the Forest-Steppe zone of Ukraine, the predominant type of land use is agricultural activity with land plowing. Some farms practice minimizing tillage, which, in particular, should affect the value of the indicator of land degradation.

With some convention of such an approach, the indicator allows to display in the map space the data of changes in the condition of the land, the loss of soil organic carbon according to remote sensing data and the nature of soil degradation for the selected time interval. Due to difficult economic conditions, part of the lands for the period 2001-2019. was not used in agricultural production, some fields were overgrown with woody vegetation and were not actively cultivated, which was reflected in the indicators of indicator 15.3.1. At the same time, most of the lands (over 66%) did not undergo positive or negative changes during the studied period.

The use of indicators of soil condition, monitoring of the development of degradation processes based on operational data and the possibility of their comparison for different *time intervals plays a particularly important role in the context of the impact of global climate changes on the soil cover, prospects for agricultural production and, in general, on the quality of life of people.*

Keywords: *sustainable development goals, soil degradation, land use indicators, geoinformation models, remote sensing data.*

Topicality.

The United Nations Convention to Combat Desertification (UNCCD — United Nations Convention to Combat Desertification) introduced a system of indicators (UNCCD, 2021) that allow for a global assessment of the condition of agricultural lands and the risks of development of degradation processes as a result of their use. Thanks to this, it is possible to conduct a spatio-temporal analysis of changes in land cover, in particular, changes in the content of organic carbon, soil productivity, changes in the type of land use (arable land, forested areas, pastures, wetlands, built-up areas, water surfaces, etc.) both on a global scale levels, as well as for a specific territory (group of countries, a country or its administrative unit).

Since Ukraine joined the UN Land Degradation Neutrality Target Setting Program, such an analysis at the national and local levels is desirable and necessary.

The aim of the research is to establish the localization of land degradation processes in the Kyiv region according to indicator 15.3.1 of the goals of sustainable development by means of the Trends.Earth module of the QGIS program, for the period 2000-2019 (the latest data at the time of writing the article), to determine the main reasons and predominant directions of changes in the indicator during this period of time.

Analysis of recent research and publications.

In the developed world, the development of a system of integrated assessment of the state of land and the dynamics of soil cover changes has long attracted the attention of scientists, especially in connection with the challenges of recent decades associated with global climate changes and the problem of providing food for the global population (2030 Agenda for Sustainable Development, 2015). Indicators of such an assessment are most often represented by indicators that take into account a complex of a wide range of factors and allow quantitative accounting with a reflection of change trends in the case of various development scenarios (Kotykova O.I., 2017; Maryanovych M.E., 2019; Yagodzinska A.S ., 2020). A number of authors (Wessels K.J. et al., 2007; Prince, S.D., 2019; Fedorov, O.P. et al., 2019) consider the data of remote sensing of the Earth as a reliable source of operational information regarding individual indicators of land cover degradation, in particular as a result of processes erosion, pollution, violation of the fertile soil layer, dehumification, etc. (Balyuk S.A., Medvedev V.V., Zakharova M.A., 2013; Kovalenko A.O., 2018). An important publication in Ukraine in this direction is the work of a team of authors from the Institute of Space Research of the National Academy of Sciences of Ukraine (Fedorov, O.P., etc., 2019). In particular, these authors note: "... it is expected that the governments of the countries of the world will form national plans and initiatives based on the goals of sustainable development according to the available opportunities, and the goals, objectives and indicators of the global level will be adapted according to the development and security priorities of the countries." Thus, the National Program for achieving the goals of sustainable development formulates goal 15, task 15.3: "To restore degraded lands and soils using innovative technologies": at the same time, as the authors note, quantitative characteristics of the level of land degradation are absent in regulatory documents, as well as the concept " neutral level of land degradation" (Fedorov, O.P. et al., 2019).

The chosen approach makes it possible to carry out a comprehensive assessment of soil cover changes and to determine both the direction of the studied processes (degradation or improvement of the state), as well as to display the corresponding spatial and temporal changes of the soil cover cartographically by means of geoinformation systems. As part of the 2030 Agenda for Sustainable Development, Sustainable Development Goal (SDG) No. 15 is: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, halt and reverse land degradation, and halt biodiversity loss ". Target 15.3 aims to: "By 2030, combat desertification, restore degraded lands and soils, including lands affected by desertification, drought and floods, and strive to achieve a neutral level of land degradation." (FAO, 2018; Knowledge Products and Pillars. UNCCD, 2021; Trends.Earth. SDG indicator 15.3.1. description, 2021). Among the indicators developed by this organization, for the purposes of our research, Indicator 15.3.1 deserves special attention, which reflects the share of degraded land to the total land area. The average value for Ukraine is 25% (Land Portal Interactive map, 2021).

Research materials and methods.

The United Nations Convention to Combat Desertification (UNCCD, 1994) defines land degradation as "the reduction or loss of biological or economic productivity of non-irrigated or irrigated crops, pastures, forests and woodlands resulting from a combination of adverse factors, including peculiarities of land use and management practices" (UNCCD 1994, Article 1). According to this definition, the degree of land degradation for reporting under Indicator 15.3.1 is calculated as a binary (deteriorated / not deteriorated) quantitative definition using its three sub-indicators (Fig. 1), namely:

• trends in land cover type changes;

• trends in changes in land productivity,

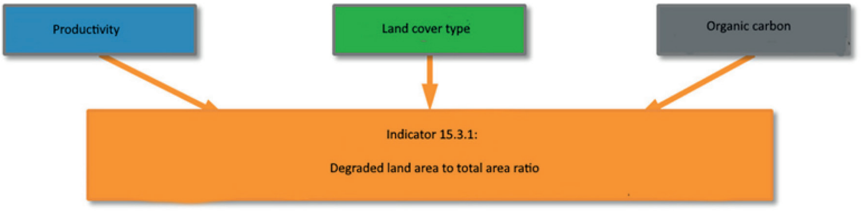

Fig. 1 Factors taken into account when calculating the indicator 15.3.1. (according to UNCCD, 2021)

• trends in changes in organic carbon reserves in the soil.

Actually, when calculating the indicator, any significant decrease or negative change in one of the three sub-indicators is considered land degradation. A positive change in the indicator is assessed as an improvement in the condition of the land.

The indicator allows individual countries to quantitatively and qualitatively assess the degree of land degradation. This assessment is useful not only for national reporting to UN commissions and reporting under indicator 15.3.1, but also for tracking progress towards voluntary Land Degradation Neutrality goals and for developing action plans to combat degradation, including including through conservation, sustainable management, reclamation, restoration and protection of land resources (Trends.Earth. SDG indicator 15.3.1. description, 2021).

The United Nations Convention to Combat Desertification (UNCCD) is the custodian institution of the Sustainable Development Goals Indicator 15.3.1. Information on this indicator has been regularly collected by this institution through a national reporting and review process since 2018, every four years. These data are available on the website of the organization unccd.int. The United Nations Convention to Combat Desertification (UNCCD) is also the lead agency for an inter-agency advisory group to further improve the methodology and tools / data options of index 15.3.1, which includes key partner FAO as well as the United Nations Environment Program (UNEP) and the United Nations Statistics Division (UNSD).

The justification and calculation methodology for the three sub-indicators is well established and recognized in the scientific literature (Wessels, K.J. et al., 2007, 2012; Kotykova O.I., 2017; Prince S.D., 2019, Alamanos, A. and Linnane, S., 2021) and in multilateral international agreements on the main climate variables and biodiversity (UNCCD, 1994; FAO, 2018).

In some countries land cover data are collected by the national statistics office, for many others land cover data are shared between different sectors (agriculture, nature conservation, forestry, etc.) and related departments or ministries. Many national space agencies have adequate means of remote sensing of land cover types. Regarding land productivity and soil organic carbon stocks, data collection is usually carried out on the ground by specialized institutions at national, regional and global levels.

The QGIS program, which one of the authors of the article has been using since 2008 for research work, is an open geographic information system with a wide range of modules that significantly expand its functionality, which allows it to not be inferior in many parameters, in particular, to the commercial development of ArcGIS by ESRI and others. Algorithms of the geoinformation system QGIS make it possible to model spatio-temporal changes and display cartographic models of the studied processes of natural resources, in particular, soils (Bogdanets, 2019).

The Trends.Earth module allows the user to calculate each of these sub-indicators spatially, generating bitmaps that are then integrated into the final map of SDG 15.3.1 indicators and create tabular arrays reporting the results potentially improved and worsened by this indicator of the areas of the study area. As the custodian agency of Indicator 15.3 of the Sustainable Development Goals, the United Nations Convention to Combat Desertification (UNCCD) has developed a Good Practice Guide to provide guidance on the calculation of Indicator 15.3.1. This document provides a brief introduction to Indicator 15.3.1 and describes how each indicator is calculated using the Trends.Earth tool. Trends.Earth uses biweekly data from the MODIS and AVHRR remote sensing resources to calculate annual NDVI vegetation indices (calculated as annual mean NDVI for ease of interpretation). These annual NDVIs are then used to calculate the corresponding performance indicators. Land productivity is assessed in Trends.Earth using three metrics derived from NDVI time series data: trajectory, efficiency, and condition. The productivity trajectory measures the rate of change in primary productivity over time. Positive statistically significant trends in NDVI would indicate potential land improvement, while negative significant trends would indicate degradation.

Within a particular ecosystem, primary productivity is influenced by several factors, such as temperature, as well as the availability of solar radiation, nutrients, and moisture. Among them, moisture availability is the most variable in time and can have a very significant effect on the amount of plant biomass produced each year. When analyzing annual NDVI data, it is important to interpret the results containing archival precipitation information. Otherwise, declining trends in productivity may be misinterpreted as anthropogenically induced land degradation, when in fact they are driven by regional variations in moisture availability.

Trends.Earth allows the user to perform different types of analysis to separate climatic causes of changes in primary productivity from those that may be the result of human land use decisions on the ground. The productivity indicator measures locally productivity relative to other similar types of vegetation on similar land cover types or bioclimatic regions of the entire study area. The model uses a combination of soil taxonomy units (using the American USDA system, provided by SoilGrids with a resolution of 250 m) and land cover types (37 land cover classes with a resolution of 300 m) to define these areas in the analysis process (Trends.Earth documentation, 2021). To assess changes in land cover, users need land cover maps covering the study area for the base and target years. These maps must be of acceptable accuracy and produced in such a way that a reliable comparison can be made. Trends.Earth uses ESA land cover type maps as its default dataset, but local maps from other sources can also be used. The integration of the three sub-indicators of the SDG indicator 15.3.1 is carried out according to the exclusionary rule, which means that if an area has been identified as potentially degraded by any of the sub-indicators, then the area will be considered as potentially deteriorating by indicator 15.3. 1. (Trends.Earth documentation, 2021).

Results and discussion. To evaluate the indicator of soil degradation, we chose a period where the base year is 2001, and the comparison year is 2019, which sufficiently reflects the dynamics of land use during this period in market conditions and allows us to assess the impact of various factors on the state of the soil cover according to this integral indicator. When working with the Trend.Earth module, the territory within the administrative boundaries of the Kyiv region was selected. As a result of data processing for the studied territory by the Trend.Earth module,

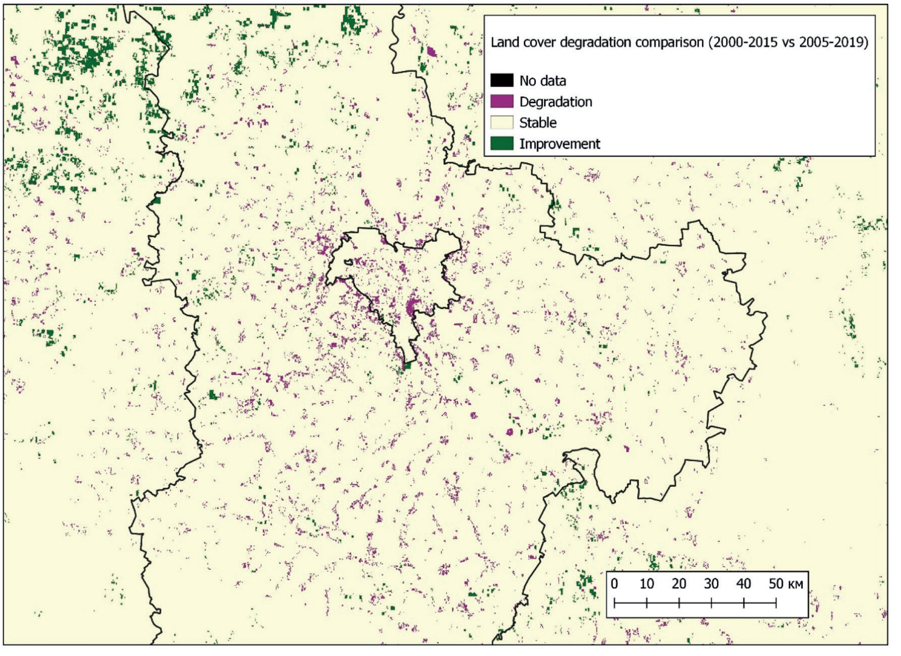

Fig. 2. Map (fragment) of the results of data analysis on soil cover degradation by the Trends module. Earth, for the period 2001-2018.

data were obtained on the state of land use (types of cover), the content of soil organic matter and indicators of land productivity according to the method described above (Trends.Earth documentation, 2021). These data were uploaded to the geographic information system environment QGIS for further analysis. The data set reflecting the trend of changes according to indicator 15.3.1 deserves special attention.

As can be seen from the map developed by us (Fig. 2), during the studied period, degradation processes prevail in the territory of Kyiv region, they are caused by various factors, in particular, intensive agricultural use of land with plowing and loss of soil organic matter and degradation due to soil erosion, primarily water erosion. At the same time, most of the lands (over 66%) did not undergo positive or negative changes during the studied period. According to the method of calculating the indicator (Trends.Earth documentation, 2021), the combined effect of land use factors, soil organic carbon content and crop productivity in the studied territory is taken into account.

Positive changes in the land degradation indicator (shown in green in Fig. 2) indicate mainly a decrease in the agricultural use of these lands, at the same time, the organic carbon content of the soil, according to the analysis of the studied territory, showed mainly negative dynamics (Fig. 3).

According to our estimates, when checking individual areas with an increased value of the land degradation indicator based on remote sensing data at various times, these are most often agricultural lands that are actively used.

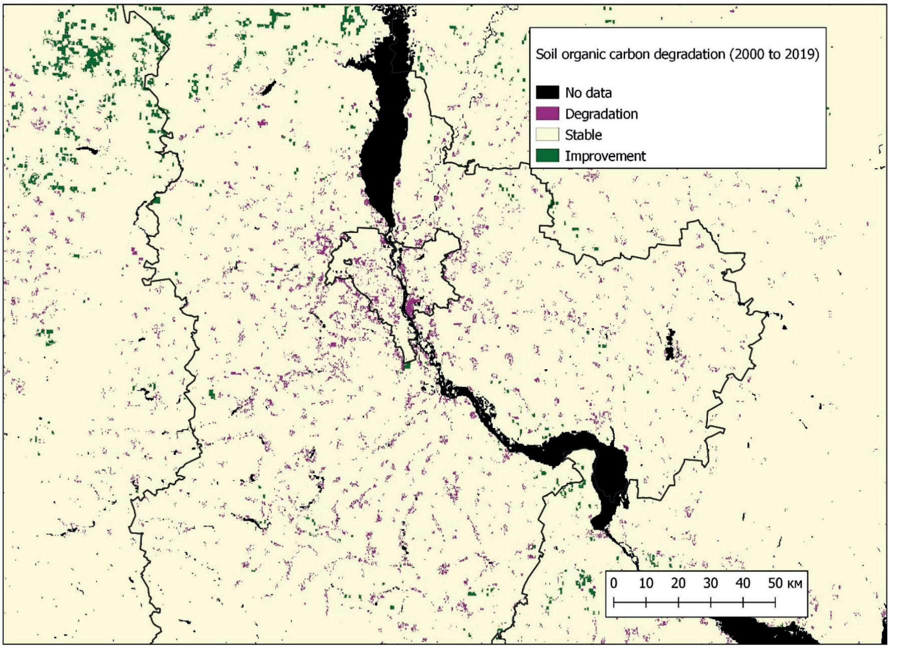

Fig. 3. Map (fragment) of the results of data analysis on soil organic carbon by the Trends module. Earth for the period 2000-2019.

To use indicator 15.3.1 in specific natural and climatic conditions, it is necessary to take into account local practices, peculiarities and traditions of farming, which will be significantly different, for example, in Ukraine and Brazil. Unfortunately, there is a limitation in the possibilities of using this indicator to characterize an individual farm or enterprise, caused by the peculiarities of the data that serve as the basis for such a calculation (resolution 250-300m).

At the same time, to calculate the indicator of land degradation using the Trends.Earth tool, it is possible to establish such changes at the level of both the country as a whole and a separate administrative region (map scale 1:1000000) and conduct a spatio-temporal analysis of such changes. Therefore, in our opinion, this tool is of considerable interest to academics and practitioners for the purposes of quantifying such changes in a defined administrative unit.

Conclusions.

With some convention of such an approach, the indicator allows to display in the map space the data of changes in the condition of the land, the loss of soil organic carbon according to remote sensing data and the nature of soil degradation for the selected time interval. In the forest-steppe zone of Ukraine, the predominant type of land use is agricultural activity with land plowing. Some farms practice minimization of soil cultivation, which, in particular, should affect the value of the land degradation indicator. Due to difficult economic conditions, part of the lands for the period 2001-2019. was not used in agricultural production, some fields were overgrown with woody vegetation and were not actively cultivated, which was reflected in the indicators of indicator 15.3.1. At the same time, most of the lands (over 66%) did not undergo positive or negative changes during the studied period. When using remote sensing data, which serve as the basis for calculating land degradation indices, using the Trends. Earth tool, it is possible to establish such changes at the level of the administrative region (map scale 1:1000000) and conduct a spatio-temporal analysis of such changes. At the same time, it is difficult to ensure higher spatial accuracy at the level of a separate territorial community or farm, which is due to the peculiarities of the data that serve as the basis for such a calculation. The use of indicators of soil condition, monitoring of the development of degradation processes based on operational data and the possibility of their comparison for different time intervals plays a particularly important role in the context of the impact of global climate changes on the soil cover, prospects for agricultural production and, in general, on the quality of life of people.

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ІНДИКАТОРИ СТАЛОГО РОЗВИТКУ БЕЗПЕКИ ВИКОРИСТАННЯ ЗЕМЕЛЬ ТА ОЦІНКА РОЗВИТКУ ДЕГРАДАЦІЙНИХ ПРОЦЕСІВ ҐРУНТОВОГО ПОКРИВУ З ВИКОРИСТАННЯМ ГЕОІНФОРМАЦІЙНИХ МОДЕЛЕЙ

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Анотація. *У статті описано деякі із прийнятих ООН індикаторів сталого розвитку безпеки землекористування, пов’язаних з розвитком процесів деградації ґрунтів, підходи до оцінки розвитку деградації ґрунтів за допомогою засобів математичного моделювання, а саме геоінформаційних моделей.*

Індикатор 15.3.1 цілей сталого розвитку відображає відношення площі деградованих земель до загальної площі земель оцінюваної території, а деградація розглядається як інтегральний показник таких параметрів, як продуктивність землі, вміст органічної речовини у ґрунті та тип землі. використовувати. Встановлено, що при використанні даних ДЗЗ, отриманих з відкритих джерел, які є основою для розрахунку індексів деградації земель інструментом Trends.Earth через програмне забезпечення QGIS, можливе встановлення таких змін на адміністративному рівні (масштаб карти 1: 100000) і просторово-часовий аналіз таких змін.

Водночас важко забезпечити вищу просторову роздільну здатність, яка б дозволяла проводити аналіз на рівні окремого господарства чи підприємства. Це пов'язано з просторовою роздільною здатністю даних, які є основою для такого розрахунку.

За певної умовності такого підходу індикатор дозволяє відображати в просторі карти дані про зміни стану земель, втрати органічного вуглецю ґрунтів за даними ДЗЗ та характер деградації ґрунтів за обраний інтервал часу. . У лісостеповій зоні України переважаючим видом землекористування є сільськогосподарська діяльність з оранкою. Деякі господарства практикують мінімізацію обробітку ґрунту, що, зокрема, має вплинути на значення показника деградації земель. Через складні економічні умови частина земель за період 2001-2019 рр. не використовувався у сільськогосподарському виробництві, окремі поля заросли деревною рослинністю та активно не оброблялися, що відображено в показниках показника 15.3.1. При цьому більшість земель (понад 66%) не зазнали позитивних чи негативних змін протягом досліджуваного періоду.

Використання індикаторів стану ґрунтів, моніторинг розвитку деградаційних процесів на основі оперативних даних та можливість їх порівняння за різні часові інтервали відіграє особливо важливу роль у контексті впливу глобальних змін клімату на ґрунтовий покрив, перспективи на сільськогосподарське виробництво та, в цілому, на якість життя людей.

***Ключові слова**: цілі сталого розвитку, деградація ґрунтів, індикатори землекористування, геоінформаційні моделі, дані ДЗЗ.*

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