The Land Degradation Estimation Remote Sensing Methods Using RUE-adjusted NDVI

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***Abstract*—State of the art methodologies for land degradations assessment accepted by United Nations, Food and Agriculture Organization and other official organizations that work on food security problems are based on the use of satellite data. In this case, the basis for the land degradation maps are vegetation indices, calculated using combinations of multispectral channels of satellite images. Evaluation of the land degradation state and trends is grounded on the analysis of land productivity maps changes over time (land productivity trend), land cover changes and carbon stocks changes.**

The most common methodology for the land degradation assessment is used for the UN Sustainable Development Goal 15.3.1 "Proportion of land that is degraded over total land area" calculation. This study considers the improvement for the calculation of land productivity / degradation based on the use of means of net primary productivity (NPP). For the NPP calculation we used open databases of satellite products of MODIS with spatial resolution 500 m and Landsat-8 with 30 m spatial resolution in the Google Earth Engine cloud platform. The satellite data for 2015 to 2019 years were used to build land productivity map and determine the areas of land degradation, productive and sustainable land for the territory of Ukraine. The use of NPP improve the land productivity assessment by consideration of agroclimatic conditions. The results were compared with product of Trends.Earth (official QGIS built-in plugin) which calculate land degradation maps by the UN methodology. The total areas of productive, degraded and sustainable land were calculated for the territory of Ukraine for 2015-2019 period.

Keywords*—*land degradation, land productivity, NDVI, NPP, Trends.Earth, SDG 15.3.1

I. INTRODUCTION

The problem of land degradation is acute worldwide due to the intensification of anthropogenic impact on the environment. Land degradation is a phenomenon that reduces agricultural productivity, lead to deterioration of the economy situation and reduced food security factors [1] and has become an integral part of today's industrial use of land resources. The problem of land degradation and productivity assessment is very important for Ukraine, because today we are on the eve of the opening of the agricultural land market. Therefore, the definition of indicators of land degradation and assessment of land productivity is an urgent scientific task, which should be solved using remote sensing.

The basis for the construction of so-called maps of land degradation are vegetation indices, which are obtained on the basis of combinations of multispectral channels of satellite images and biophysical modeling of plant conditions. Such indices are Normalized Differential Vegetation Index (NDVI) [2][3], Net Primary Productivity (NPP) in order to consider climate changes (global warming [4]), or examined platform levels (in situ, airborne, and satellite) for sensors [5], Leaf Area Index (LAI) and other biomass characteristics.

Combination of weather data and NDVI provide possibility to generate new vegetation index, called NPP. The use of NPP instead of NDVI improve general UN SDG 15.3.1 methodology by the consideration of agroclimatic conditions. This improvement avoid the gap of general methodology – it take in to account climate and the impact of climate on the land productivity. In this paper we assess the land degradation using both general and improved methodologies and compare the results.

II. SATELLITE DATA

Today, satellite data and products are publicly available and can be used as sources of information to analyze productivity and land degradation. By integrating satellite data with disparate socio-economic information and soil maps, a methodology for assessing sustainable development indicators can be developed.

In this paper were used the appropriate satellite data:

1. For NPP – MODIS (MOD17A3HGF.006: Terra Net Primary Production Gap-Filled Yearly Global 500m) [6]

2. For precipitation – GPM: Monthly Global Precipitation Measurement (GPM) v6 [7]

3. For NDVI – the dataset NOAA CDR AVHRR NDVI: Normalized Difference Vegetation Index, Version 5. [8].

A set MODIS (MOD13Q1) satellite data of annual measuring with a spatial resolution of 250 m was used to calculate the sub-indicator of land productivity with the help of the service Trends.Earth.

III. METHODOLOGY

This paper considers the methodology for calculating land productivity based on the satellite data recommended ny UN and its modification that use NPP indicator instead of NDVI.

Using an index of Net Primary Productivity (NPP) it is possible to separate areas for which the deterioration or improvement of this indicator can be explained only by human activity and areas for which land degradation can be explained by weather conditions. There are many additional instruments which allow to estimate the NPP using Rain [9] or Light Use Efficiency [10].

In order to distinguish between declining productivity due to land degradation and other factors, it is necessary to mask areas where deterioration or improvement in degradation rates may be due to important climate variables. Therefore, the algorithm for classical calculating land degradation can be expressed in 4 points [11]:

1. The territory where precipitation can be used to determine NPP must be identify. It means that relationship between productivity and precipitation must be positive.

2. For these areas RUE should be calculated. The other zones must be masked together with cities (productivity decreases due to reduced rainfall).

3. NDVI trend is considered for areas with a positive ratio but a reduced RUE, as well as for areas with a negative ratio between NDVI and precipitation. This is called RUE-adjusted NDVI.

4. Land degradation estimated using RUE-adjusted NDVI (if this NDVI is negative).

In this work the land degradation indicator was calculated using the Google Earths Engine cloud platform using land productivity maps and precipitation for the territory of Ukraine from 2015 to 2019.

To obtain reliable results of the land degradation index according to the time trend of NDVI trend, the improved methodology for calculating degradation maps were used. The method for the SDG indicator 15.3.1 calculation, the methodology of which based on the service Trends.Earth for land change tracking. It was produced as part of the project "Enabling the use of global data sources to assess and monitor land degradation at multiple scales" (http://trends.earth/docs/en/about/general_info.html), funded by the Global Environment Facility.

This method for creating of the land productivity map is based on the use and analysis of a long-term trend of change in the vegetation index NDVI, obtained on the basis of satellite data [12]. This approach makes it possible to calculate sustainable development indicators 15.3.1 and 2.4.1. Typically, low spatial resolution data such as MODIS are used, which have a large set of daily historical data. But to improve the spatial resolution of satellite data was used Sentinel-2, which provides data of high spatial resolution of 10 m with a periodicity of 5 days, combining with Landsat-8 data with a spatial resolution of 30 m with a panchromatic channel of 15 m, to create a collection of harmonized high-resolution satellite data with a time resolution of 2-3 days [13]. This combination significantly increases the amount of important information for trend analysis, makes the methodology more applicable for calculating the long-term trend of change in vegetation indices.

Therefore, using the built-in plugin Trends.Earth in cross-platform geographic information system (QGIS), a sub-indicator of Productivity was calculated according to the methodology of calculating the land productivity index for sustainable development goals 15.3.1.

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IV. RESULTS

As a result, were calculated the RUE-adjusted NDVI trend and productivity trajectory degradation map for the territory of Ukraine for 2015 and 2019.

For first method were using RUE-adjusted NDVI trend based on identifying the dependence of land productivity (NPP) on precipitation. The negative values of NDVI trend beginning from point -0.15 can be seen as a sign of land degradation. The value of NDVI trend for stable state of land was taken from -0.15 to 0.15. Improvement land is equal for the territory where trend is more than -0.15. The result is presented on the Fig. 1.

The overall square of the land degradation was calculated using QGIS plugin Trends.Earth. On the Fig. 1 damaged areas of land are marked in red.

For second method were using the classic calculation of land degradation indicator 15.3.1 by plugin Trends.Earth. As in first one this map has 3 classes of land productivity which corresponds to the previous. The result is presented on the Fig. 2.

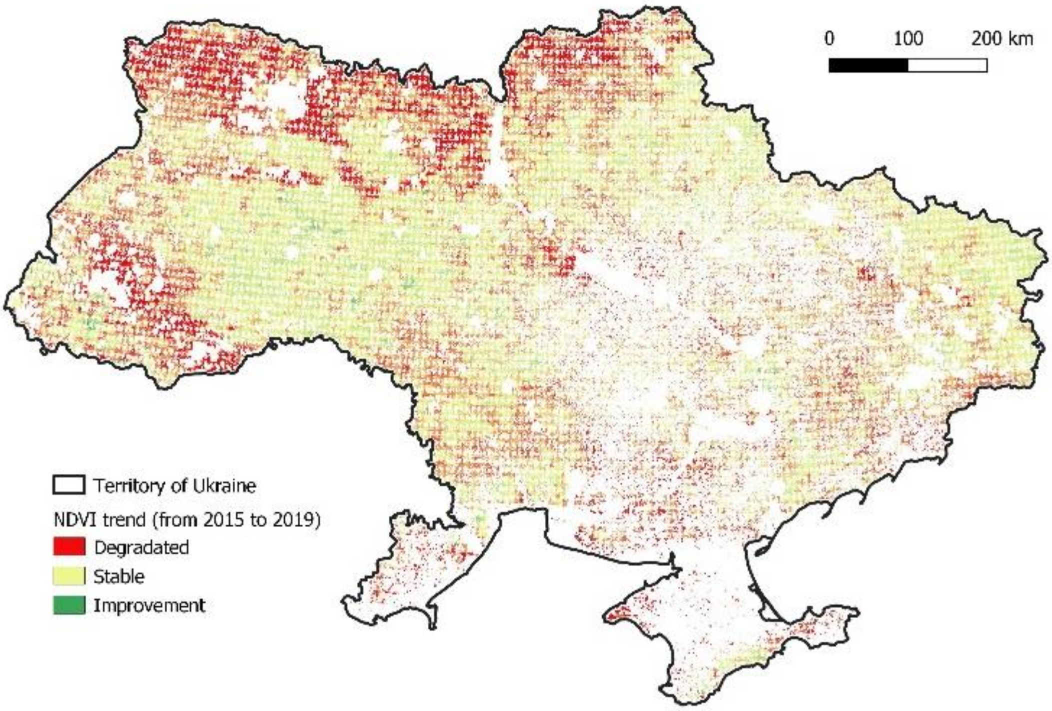

Fig. 1. Land poductivity map calculeted by RUE-adjusted NDVI trend method for the territory of Ukraine from 2015 to 2019 period

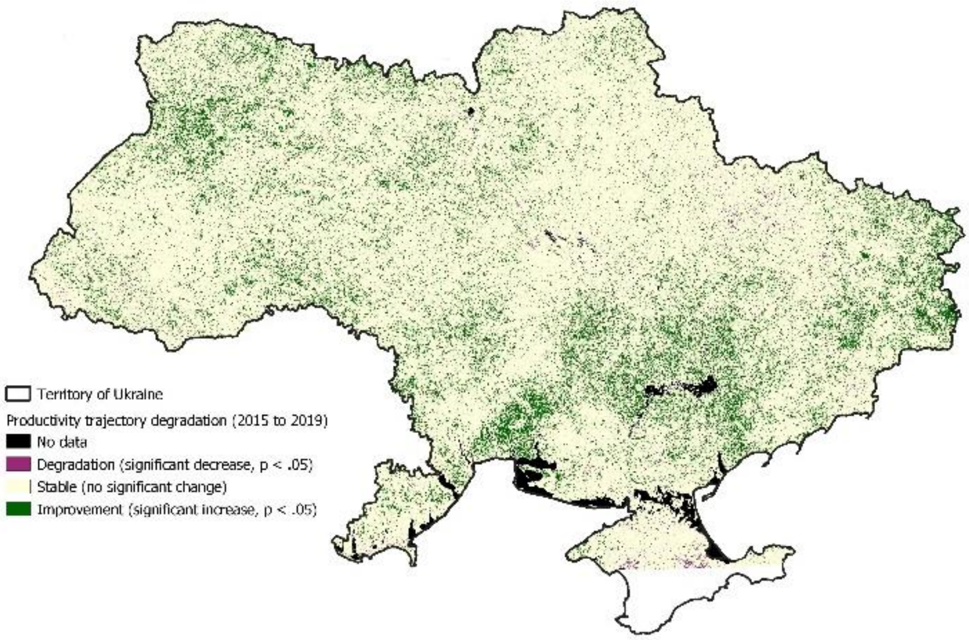

Fig. 2. Productivity trajectory degradation calculated by Trends.Earth for the territory of Ukraine for 2015-2019 period

Using satellite image analysis tools, the areas of degraded, improved and stable land plots were calculated for both obtained land productivity maps. To validate the performance map calculated by RUE-adjusted NDVI method, the results were compared.

Comparing land productivity data calculated on the basis of the methodology for the Sustainable Development Goals Indicator 15.3.1 and calculated using the RUE-adjusted NDVI method, the following values of areas were obtained (the results are shown in Table I):

TABLE I. RESULTS OF COMPARING BOTH METHODS

Class of land productivity	**Square, ha**		
	Trends.Earth	**RUE-adjusted NDVI**	**Compared**
Stable	50 605 781	39 758 879	33 203 136
Impovement	7 429 868	6 900 663	1 054 377
Degradated	481 649	1 463 677	14 606

The method of RUE-adjusted NDVI trend can be improved by usind methodology of NPP calculation for definition of land cover productivity of the territory of Ukraine in the presence of possibility to combinate weather and satellite (NDVI).

V. Conclusions

Measures aimed at stopping and maintaining a neutral level of land degradation are high on the international agenda for Sustainable Development Goals [2]. The result of such activities is the current methodology for assessing the level of productivity / degradation using satellite data [3] to obtain both a qualitative and a quantitative measure of the state of the land, which the authorities can operate for a targeted and effective policy of restoration. The methodology for calculating net primary productivity is a way to increase the determination of land productivity through the use of vegetation index NDVI and improve general UN SDG 15.3.1. The state of land cover can determine by using NDVI time series, as well as the class of land productivity (degraded, improved or stable).

For the territory of Ukraine this task is also paramount and is solved with the use of new techniques (including Nexus Approach [14]). The land degradation indicator was calculated for the territory of Ukraine in 2015 and 2019 based on the methodology, which includes accounting for net primary productivity, the impact of precipitation on the soil and the value of vegetation index (NDVI).

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