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SPACE RESEARCH IN UKRAINE

2018—2020

Report to COSPAR

The Report Prepared by the Space Research Institute of NAS of Ukraine and SSA of Ukraine

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Report to COSPAR summarizes the results of space research performed during the years 2018—2020. This edition presents the current state of Ukrainian space science in the following areas: Space Astronomy and Astrophysics, Earth observation and Near-Earth Space Research, Life Sciences, Space Technologies and Materials Sciences. A number of papers are dedicated to the creation of scientific instruments for perspective space missions. Considerable attention paid to applied research of space monitoring of the Earth. The collection can be useful for a wide range of readers, interested in space research.

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FOREWORD

The publication represents the results of space research and developments, performed by leading Ukrainian scientific teams in the years 2018–2020. Unfortunately, during this period, Ukrainian scientists were not supported by the National Space Programme, which was not developed and adopted by the Parliament. Therefore, this edition includes the works supported by the National Academy of Sciences and international grants in the following areas: Space Astronomy and Astrophysics, Near Earth Space Research, Space Biology, Earth Observation from Space, Space Technologies and Materials Science (according to the classification of COSPAR).

Section "Space Astronomy and Astrophysics" represents the review of the Institute of Radio Astronomy on synchronous coordinated ground-based support of space missions using Ukrainian radio telescopes UTR-2.

The second section includes the results of studying the processes in the Earth's atmosphere — ionosphere — magnetosphere system. The articles of Space Research Institute specialists are devoted to the mechanisms of seismic-ionospheric coupling and creation of operational service for local geomagnetic forecast. Researchers of the Institute of Technical Mechanics present the modeling of complicated interactions of a spacecraft with Earth ionosphere. The new concept of the particle microbursts satellite experiment advanced by the team of scientists including experts of the Institute of Radio Astronomy. Three articles reviews the different aspects of the interactions of Geospace environment with natural and man-made objects.

The next series of review articles represents the Ukrainian science centers activity in the Space Biology, Space Observation of the Earth and Space Technologies. Most of them dedicated to perspective space missions and utilization of space data for assessment the sustainable development goals.

In general, the presented review illustrates the current state and multidimensionality of the subjects of Ukrainian space science. Some of the results were obtained in the framework of international projects, programs and grants, including the European program Horizon 2020, and most of the results had been reported at the annual Ukrainian Conference on Space Research, international seminars and conferences.

The collection is intended for space scientists, post-graduate students and readers interested in space research.

SDG INDICATOR 11.3.1 WITHIN HORIZON-2020 SMURBS

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Introduction

Sustainable Development Goals (SDGs) indicators assessment is a very important task for today's global scientific communities [1]. Remote sensing data has been used to solve many problems in the process of ensuring sustainable land use and city's management [2]. One such example is assessment of SDG indicator 11.3.1: "Ratio of land consumption rate to population growth rate". It is tier 2 indicator, which has methodology for calculation, but data sources for estimation are still uncoordinated.

This work proposes several simplifications that give possibility to calculate land consumption [3, 4], using built-up area maps and demonstrate how this methodology works on the world cities. As a result, generation of high quality local or global land cover maps on regular basis, can solve the task of accurate indicator 11.3.1 estimation.

The indicator 11.3.1 is proposed two ways for this indicator calculation [5]. The first one is for the country level for goal monitoring and comparison of countries. For this purpose, indicator better to build on such quality global products as GHSL. The second one is for the local city level and it is better to use the local data that can be obtained and more applicable for these communities.

Google Earth Engine (GEE) platform provides the great opportunities for this task – possibility to use large satellite data sets with implemented classification approaches [6, 7] and implementation of local data. Within Horizon-2020 SMURBS project, Space Research Institute developed approach [8] for 10 meters land cover maps classification for urban growth assessment [9] in GEE platform that can be used for each city in the world.

Data

Satellite data. The time series of SAR Sentinel-1 acquired from 01-04-2016 to 25-10-2016 [10, 11] and cloud free images of optical Sentinel-2 satellite [18] were used for built-up area maps building for Kyiv in 2016, and cloud free images of optical Landsat-5,7 were used for built-up area maps building for Kyiv in 2000. In particular, for Kyiv city in 2016 were available 8 images of Sentinel-2, and 3 and 5 images of Landsat-5,7 respectively, which are presented in the Table 1.

The following pre-processing steps are used for Sentinel-1 data: apply orbit file, border noise removal, thermal noise removal, radiometric calibration, orthorectification and filtration with window 3 × 3. The L1C optical Sentinel-2 data were used for composites creation. The free cloud platform Google Earth Engine was used for the Random Forest (RF) algorithm implementation. All of satellite data are available in this platform.

Train and test data. Train and test data were generated by photointerpretation [13], using optical Sentinel-2 data for 2016 and Landast-5,7 for 2000. The artificial objects are the main type of land cover which must to be identified [14], so the test and training data contain two classes, which are presented in Table 2.

Auxiliary data. As additional data sets were used the Global Human Settlement Layer (GHSL) for the products comparison and Global Forest Change layer for products validation.

Table 1

Satellite images for Kyiv city in 2000 and 2016

	Sentinel-2 (2016)	Landsat-5 (2000)	Landsat-7 (2000)
Dates of images	28.04, 17.06, 17.07, 06.08, 09.08, 26.08, 29.08, 08.09	28.04, 24.07, 09.08	06.05, 07.06, 14.06, 25.07, 17.08

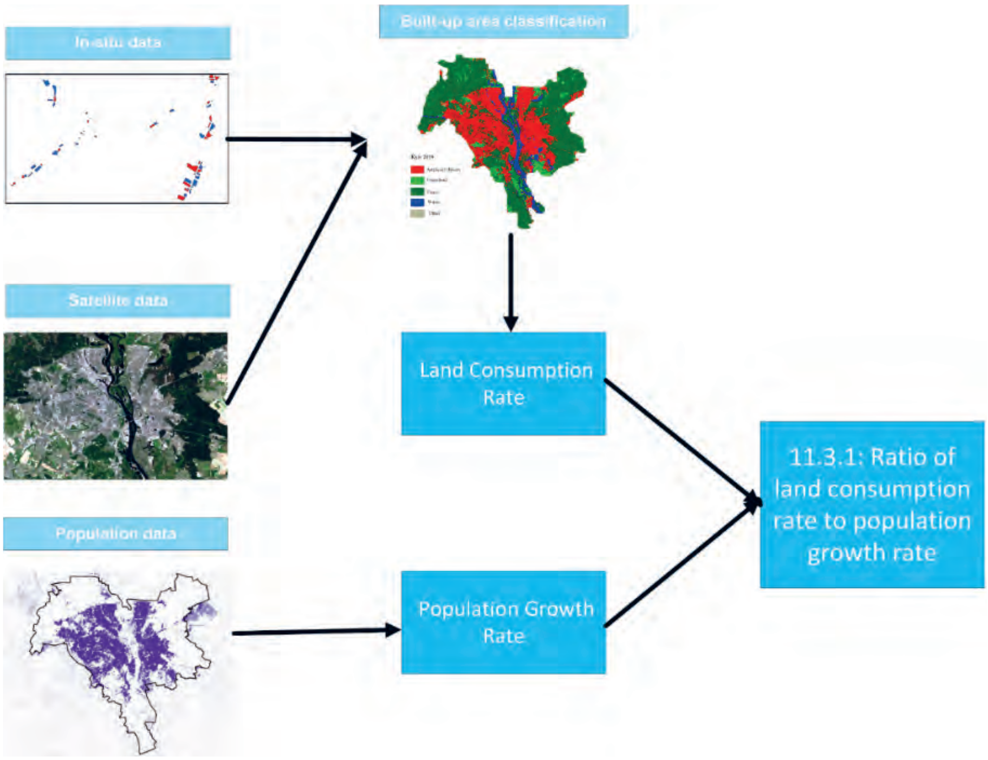

Fig. 1. Methodology for indicator 11.3.1 estimation using satellite data and population statistics

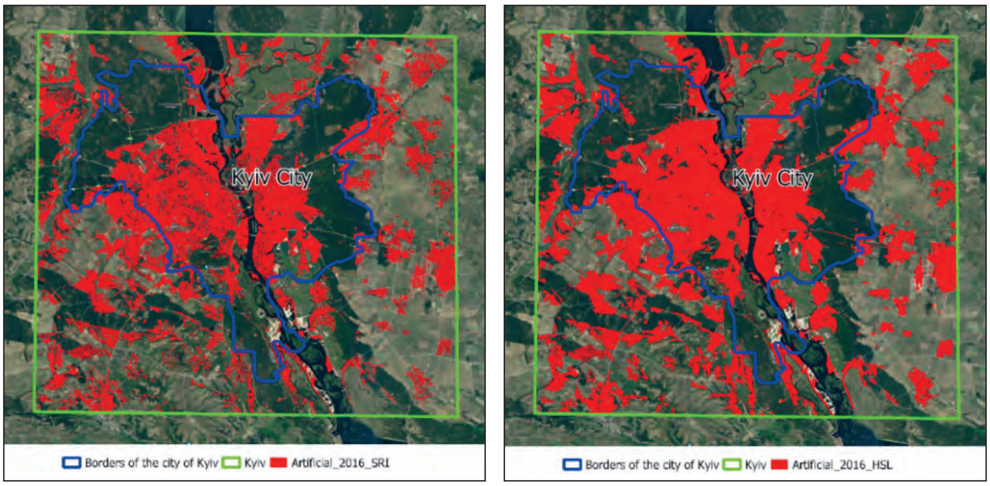

Fig. 2. The map of artificial objects for Kyiv in 2016, (*a*) – RF algorithm, (*b*) – GHSL product)

Methodology

Global human settlement layer validation and comparison with local land cover map. It is proposed to use two approaches for the built-up area validation [15, 16]. The first one needs the calculation of the confusion matrix for each of the set years using the independent test samples, and thus estimate the overall accuracy of the artificial objects. The second approach involves the use of an additional independent layer of green areas to estimate the artificial objects that intersects with it and measure this type of errors. Such an independent layer is the Global Forest Change layer (created at the University of Maryland). As a result, the intersection of artificial and green areas will be calculated and their percentage relative to the total area of the forest estimated.

Table 2

Train and test data distribution

	2000		2016	
	Train	Test	Train	Test
Artificial	30	29	57	57
Non artificial	95	96	160	161
Total	125	125	217	218

Indicator 11.3.1 estimation. Fig. 1 shows the methodology for SDG indicator 11.3.1 calculation with two included sub-indicators.

First sub-indicator is population growth rate and to estimate it, there is a need for reliable statistics with high update rate. In this reason, the best data source is statistics provided by government city administrations. For indicator estimation on country level it is possible to use UN statistics [17] and global products as GHSL population layer.

Population growth rate (PGR) is logarithm of two years' population numbers ration

$$PGR = \mathrm{In}(Popt_{(t+n)} / Popt_t) / (y),$$

where $Popt_t$ is population for year t, $Popt_{(t+n)}$ is population for year $(t + n)$, (y) is a numbers of years between measurements.

Land consumption rate (LCR) estimation [11] is more complex, for this reason built-up area map is required. Built-up area map can be received from land cover classification maps or artificial surface maps. The best way to estimate LCR for city scale is build land cover map using local training data and free available satellite data as Sentinel-2 and Sentinel-1 fused in one-time series. On country or region level it is possible to use global products such as GHSL built-up area layer.

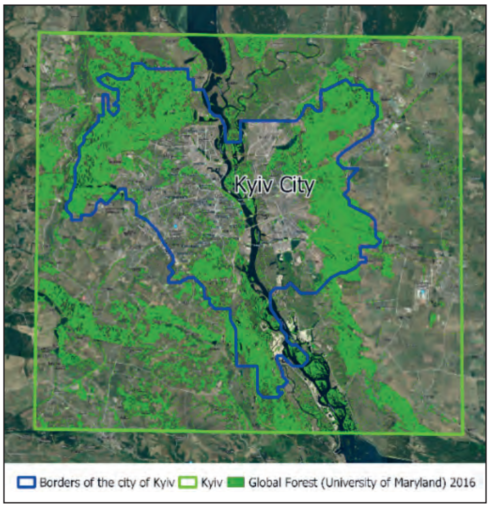

Fig. 3. Forest mask for the Kyiv city of 2016 (based on the Global Forest Change layers)

LCR calculation is similar to PGR. LCR is equal to logarithm of two years built-up area ratio

$$LCR = \mathrm{In}(Urb_{(t+n)} / Urb_t) / (y),$$

where Urb_t is built-up area for year t, $Urb_{(t+n)}$ is built-up area for year $(t + n)$, (y) is a numbers of years between measurements.

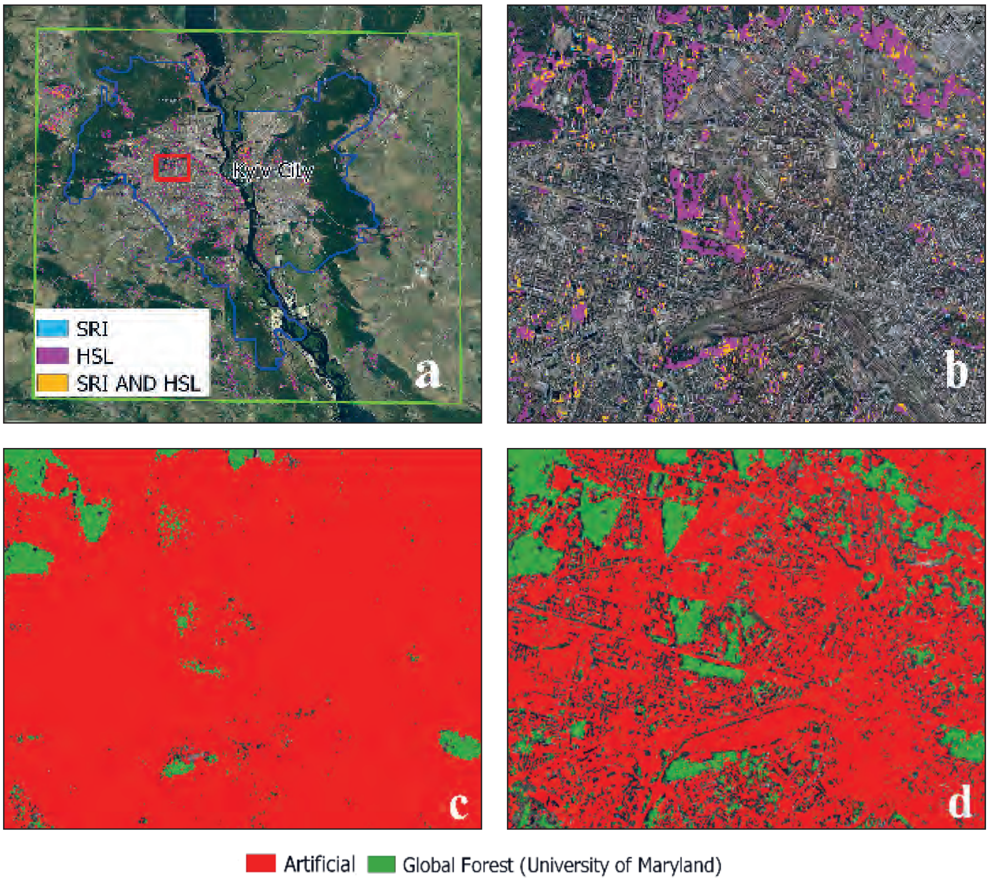

Fig. 4. Intersection of a forest mask from the Forest Mask for Kyiv City 2016 (based on the Global Forest Change layers). Artificial Object Mask: *c* – GHSL, *d* – RF

Table 3

The results of intersection green space with artificial object masks

The intersection layer	Area, ha	%, relative to the forest
SRI	58.93	0.75
GHSL	582.61	7.41
SRI and GHSL	165.26	2.10

Table 4

Land consumption rate and SDG indicators 11.3.1 based on local SRI maps and GHSL

Land Consumption Rate by SRI map	0.074
Land Consumption Rate by GHSL	0.044
SDG 11.3.1 by SRI map	4.758
SDG 11.3.1 by GHSL	2.845

SDG indicator 11.3.1 or ratio of land consumption rate and population growth rate (LCRPGR) can be calculated by formula:

$$LCRPGR = LCR / PGR.$$

Results

Validation and comparison of local land cover map and GHSL. The city is constantly expanding relative to its official boundaries. That is why the map was built with a buffer around the city (on the Fig. 2 it is marked in green). The Fig. 2, *a* presented the artificial object map (SRI maps) based on RF algorithm made on local data in GEE. The confusion matrix based on the independent test samples was calculated to validate the generated map. The overall accuracy is 85,2%. The product of the GHSL based on SAR Sentinel-1 data with spatial resolution 20 meters was used for another way to validate the classification map. This product contains the artificial objects for all world for 2016. The Fig. 2, *b* presented the part of the GHSL for Kyiv city. The overall accuracy based on independent test samples is 72.6 % which is a good result for the global product with spatial resolution up to 20 m. The main problem of this product is the presence of other objects that fall into the mask. In particular, it can be forest strips, trees, forests, parks, gardens etc. The reason is spatial resolution that causes effect of mixed pixels. But, due to that all cities in the world built on one model and have similar characteristics, usage of this global dataset is the best way for global indicator 11.3.1 assessment.

During experiment decided to use the Global Forest Change layer (created by the University of Maryland) for further validation. Granule data with top-left corner at 60°N, 30°E for Kyiv was used for this purpose. Based on the treecover2000 layer, the operations were performed to obtain a forest mask for 2016 (taking into account the layers lossyear_60N_030E1 and gain_60N_030E1). Given that the forest values were encoded as a percentage per output grid cell, in the range 0–100, a threshold of values greater than 30 was selected after the final forest cover was formed. As according to the visual estimation based on high resolution satellite data, such a threshold provides the best coverage of green area. The result is presented on the Fig. 3.

Using the resulting layer, an intersection of the green spaces and artificial objects was carried out (Fig. 4, *a*, *b*). Blue indicates the intersection of the forest layer with the result based on SMURBS approach, pink color is with GHSL, and orange is with two maps together. As can be seen in the figure, most pixels are pink (Fig. 4, *b*).

An area which was obtained is presented in the Table 3. Colors in the Table 3 correspond to colors on the Fig. 4, *a*. This area can be interpreted as the area of tree cover that was misclassified as artificial surface for both maps.

The obtained results confirm the accuracy of the constructed maps of artificial objects in Kyiv. The best performance based on RF algorithm map is provided by the spatial resolution 10 meters and usage of local data. In the future, it is planned to create maps of the same type for other set years (including 2020) and it further using within the HORIZON 2020 program, in particular the SMURBS / ERA-PLANET project [18, 19].

SDG indicator 11.3.1 built on local and global data comparison. Built-up area map for Kyiv 2000 was built using in-situ training samples [20], Landsat-5 and Landsat-7 satellite data with 83.4 % accuracy. This map used for initial year built-up area calculation for LCR. Cover map was used for 2016-year built-up area estimation. The similar year's maps were chosen from GHSL and on both data sources, land consumption rate was calculated. The local statistics provided by municipal statistical service was used to estimate population growth rate. Table 4 shows result of this experiment. As shown, difference strongly affect land consumption rate and in cases for city level indicator assessment it is better to use local data.

Conclusions

The results show that GHSL have high accuracy for country or regional level SDG indicator assessment. Due to this indicator informative and useful on high scale (city scale). For this purpose, it is better to use local data and satellite data with higher spatial resolution. That can improve accuracy of indicator calculation. Land cover classification approach in GEE developed in SMURBS project provide good results with 10 m resolution and can be used in different cities to build similar built-up area maps with implementation of local data.

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Звіт для COSPAR узагальнює результати космічних досліджень, проведених протягом 2018—2020 років. У цьому виданні представлено сучасний стан української космічної науки за такими напрямами: космічна астрономія та астрофізика, спостереження Землі та навколоземні космічні дослідження, науки про життя, космічні технології та науки про матеріали. Низку робіт присвячено створенню наукового обладнання для перспективних космічних місій. Значну увагу приділено прикладним дослідженням космічного моніторингу Землі. Видання може бути корисним для широкого кола читачів, які цікавляться космічними дослідженнями.

Наукове видання

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