Air Quality as Proxy for Assesment of Economic Activity

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***Abstract*— In Ukraine most of citizens and economic activity are concentrated over urban city centers and city functional areas. Thus, Air Quality and, in particular, levels of fine particulate matter (e.g., $PM_{2.5}$ and PM_{10}) over cities can be a proxy for assessment of economic activity and density of city populations. Since the russia invasion to Ukraine started on 24 of February 2022 according to UNHCR (the UN Refugee Agency) 8 million refugees from Ukraine have now been registered across the Europe. Almost 7 million more are displaced within the country. On the other hand, there is no official statistics from national statistical service showing current influence of invasion on city economic activity or inhabitants amount. Thus, such a proxy can be used to see current situation by analyzing of particulate matter time series. In this work we compare averaged annual cumulated $PM_{2.5}$ for 2018-2021 years with values for 2022 and estimate the correlation them with publicly available statistics on migration to see some relations. Global Sustainable Development Goal (SDG) indicator 11.6.2, "Annual mean levels of fine particulate in cities (population weighted)" is being extended for 2022 and compared with previous years.**

Keywords—$PM_{2.5}$, CAMS, Air Quality, Functional Urban Area, economic activity, migration, disasters

I. Introduction

Fine Particulate matter (PM) is a complex mixture of solid and liquid particles that are suspended in the air. These particles can be emitted directly from various sources such as factories, power plants, transportation, and wildfires, or they can be formed in the atmosphere through chemical reactions in the industry. Economic activity can have a significant impact on the levels of particulate matter in the air as well. Industries, transportation, and other economic activities can emit significant amounts of PM into the air, leading to increased levels of pollution. The burning of fossil fuels, such as coal and oil, is a major contributor to PM emissions. Thus, PM concentrations can be considered as indicator of increasing or decreasing economical activities or city population amount (at least via personal transport daily exploitation) [1].

2022 year was quite complicated to Ukraine due to the russia invasion on 24 of February. According to UN Refugee Office about 8 million of Ukraine citizens were registered across EU countries [2], about 3 million moved to russia and belarus. As for end of February 2023 there is no any available official publicly available statistical data in Ukraine that give an opportunity to check most affected by migration cities and PM levels can be an indicator whether activity has some decrease or not.

As it was shown in [3] there are various data providers in Ukraine that can be used for PM levels assessment. For example, in 2018, the current largest air quality networks, EcoCity [4] and SaveDnipro [5], appeared, and the total number of sensors from all stations in 2020 was 1183, a number which had already reached 1568 by 2021, i.e., the number of sensors per year in-creased by 385. It is the large cities that make the biggest contribution to air pollution, where the number of stations for air pollution measurement has significantly increased. However, the greatest activity still occurs in large cities, and questions regarding the absence of a small number of ground posts for air quality indicator measurement, in less populated cities or villages, remain open.

In Western Europe, one of the most popular air quality monitoring initiatives, and the most common provider of air pollution data, is the Sensor Community [6], whose developers launched the Luftdaten.info public project in 2015 in Stuttgart, Germany [7]. This project has become a catalyst for the development of similar networks of public air quality monitoring in Ukraine.

Another portal used by the residents of smart cities in the European Union is Airly [8]. It applies its own technological solutions and provides an opportunity to predict the levels of dust concentrations of fractions PM2.5 and PM10 for 1 day ahead. The service works with more than 300 local authorities, and more than 4000 devices around the world are integrated into it. Coverage over Ukraine is quite limited – mainly capital city.

The Swiss commercial project IQAir [9] uses devices to measure air pollution levels both outdoors and indoors, offering appropriate sensors and a mobile application for control and notification. IQAir operates on the world's largest free real-time air quality information platform and attracts a growing number of global citizens, organizations, and governments. The IQAir AirVisual platform integrates data collected by governments, companies, and individuals around the world.

On the other hand, density of such in-situ measurement facilities vary from city to city and for human economic activity assessment (citizens' density) over the country. It necessary to use homogeneous dataset that covers all main cities in the same manner to get comparable results.

According to [3] CAMS service (Copernicus Atmosphere Monitoring Service) operated by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Union provides comprehensive information about the Earth's atmosphere and has quite good correlation with in-situ data for the main city of Ukraine. CAMS [10] uses satellite data, ground-based observations, and ensemble models to provide accurate and timely information on air quality, climate forcing etc.

This study aims to show results of distribution analysis of time series of PM2.5 over the cities of Ukraine as well as to check correlation of these changes with refugee data from UN Refugee Office since 2022 (accumulated annual PM values also can be treated as measure of citizens economic activity in term of personal transport exploitation). Side aim is to extend approach [3] of calculation of Global Sustainable Development Goal (SDG) indicator 11.6.2, "Annual mean levels of fine particulate matter (e.g., $PM_{2.5}$ and PM_{10}) in cities (population weighted)" for 2022.

II. DATA AND METHODOLOGY

A. *Data from Copernicus Atmosphere Monitoring service*

The Copernicus Atmosphere Monitoring Service (CAMS) was developed for sharing data and processing information about the Earth's surface, aerosols, ozone, and other reactive gases, aiming to support policymakers, businesses, and citizens with enhanced atmospheric environmental information. In particular, this service provides daily hourly data regarding $PM_{2.5}$ and PM_{10} in the form of close to real-time analysis for Europe and Ukraine with a spatial resolution of 11 km. Data for 2018-2022 were considered for analysis whether 2022 have had some meaningful changes compared to 2018-2021.

B. *Functional Urban Area*

In [3] authors proposed to adopt for Ukraine concept of Functional Urban Areas (FUA) that is commonly used over European Union within Urban Atlas layer from Copernicus Land Monitoring Service (CLMS) [11].

CLMS service provides various tools and one of the most valuable one's is the Urban Atlas service, which is related to local CLMS services and provides a detailed digital city plan in vector form, which is segmented into small functional areas classified by Coordinate Information on the Environment (CORINE) nomenclature.

The Urban Atlas is a geospatial layer with high resolution, built for all European cities with a population of more than 100,000 based on satellite data [12][13]. It combines high-resolution satellite data, city segmentation by blocks and functional urban areas (FUAs), important city infrastructure, etc.

This methodology of the European Commission was chosen as the basis for selected approach for obtaining FUA for the largest cities of Ukraine [14]. The FUA can be defined in four steps:

- Identifying an urban center: a set of contiguous, high-density (1,500 residents per square kilometer) grid cells with a population of 50,000 in the contiguous cells (Global Urban Center or GUC). Global city centers were used, which were created by the Global Human Settlement Layer team in 2015 [15].
- Identifying a city: one or more local units that have at least 50% of their residents inside an urban center. The local units' boundaries for items 2 and 3 for the territory of Ukraine were used from the Humanitarian Data Exchange (HDX) platform [16].
- Identifying a commuting zone: a set of contiguous local units that have at least 15% of their employed residents working in the city.
- An FUA is the combination of the city with its commuting zone.

$PM_{2.5}$ values from CAMS service will be analyzed for identified FUAs over Ukraine (Fig. 1).

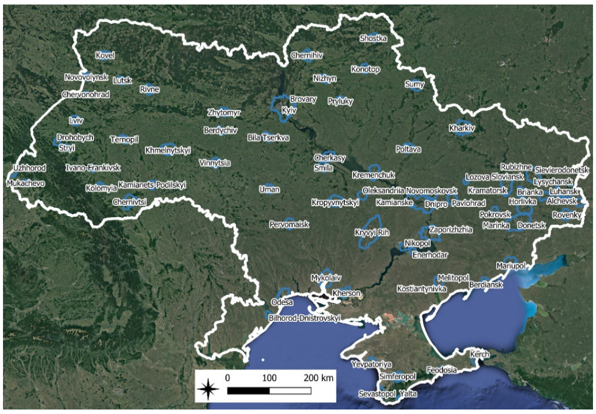

Fig. 1. Main cities of Ukraine and theis Functional Urban Areas (FUA)

C. *Population Data*

For FUA calculation, the population data from two sources were used—the Global Human Settlement Layer (GHSL) by the European Commission (2022) [17]. Study [18] demonstrated that Global Human Settlement Layer data have a much higher correlation with statistical information on the population of Ukrainian cities.

D. *Methodology*

For assessment of $PM_{2.5}$ annual variation cumulated values were used:

$$PM_x = \sum_{i=1}^{i=365} PM_i \qquad (1)$$

where PM_x - cumulated $PM_{2.5}$ value calculated for FUA of particular FUA during year x.

Basic daily values have too significant variation year to year over particular FUA that can be caused by wide list of factors (including weather and natural disasters) [19][20].

There are two main methodologies for calculating indicator 11.6.2 (UN methodology and the methodology developed within the SMURBS project), which are based on different data sets. According to these methodologies, all air quality indicators are calculated within the FUA and GUC. The general calculation equation is the same for the two methodologies and is as follows:

$$SDG_{11.6.2} = \Sigma C_n * P_n / \Sigma P_n \quad (2)$$

where C_n represents the estimated average value of $PM_{2.5}$ for the functional urban areas or global urban centers, and P_n represents the population (calculated for the FUAs and GUCs).

III. Results

For selected FUAs average cumulated values of $PM_{2.5}$ for 2018-2021 are 18-28% higher compared to 2022 cumulated values (Fig. 2).

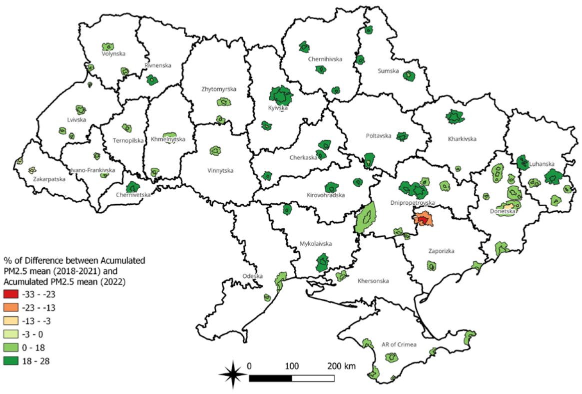

Fig. 2. Difference in % between accumulated PM2.5 mean (2018-2021) and accumulated PM2.5 mean (2022)

Comparison of annual cumulated $PM_{2.5}$ for FUAs over Ukraine demonstrate significant degrease of air pollution with $PM_{2.5}$ within last years (Fig. 3 and Figure 4).

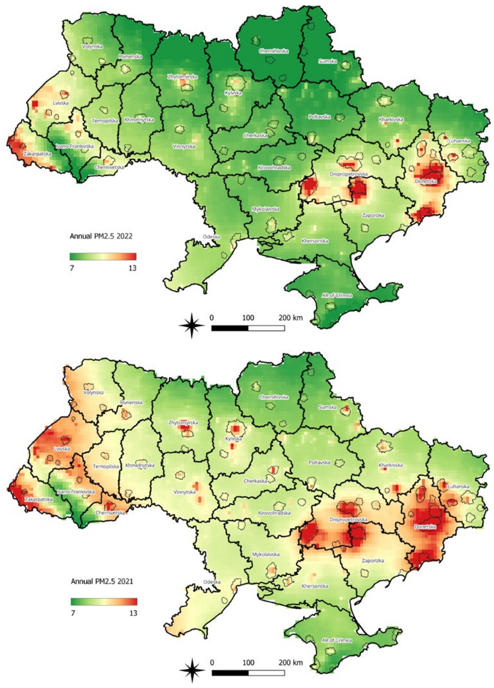

Fig. 3. Annual average PM2.5 over FUA for 2022 (top) and 2021 (bottom)

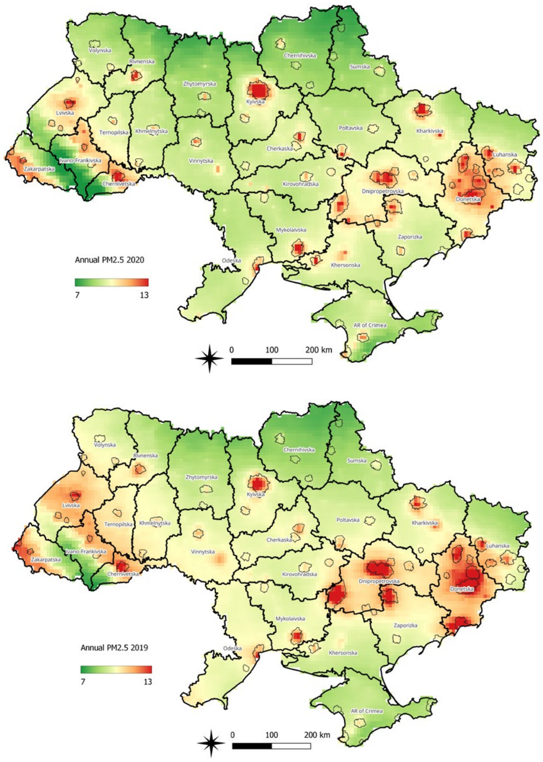

Fig. 4. Annual average PM2.5 over FUA for 2020 (top) and 2019 (bottom)

Main decrease can be identified over the cities that were under high risks of the russia invasion in central, southern and north parts of Ukraine. At the same time changes are smaller for cities in western part of Ukraine.

Fig. 5. SDG 11.6.2 values for FUA and GUC

Values of SDG Indicator 11.6.2 (Fig. 5) also demonstrate significant degrease even being calculated on GHSL data [15] for 2022.

IV. Conclusion

As for 1st February 2022 total amount of citizens of Ukraine according to census [21] was about 41 millions. With 8 million registered at European Union and about 3 million migrated to belarus and russia [2] cumulated PM values over FUAs show quite close percentage degrease as population.

From obtained results we can assume that cumulated annual PM concentrations over city FUAs can be used as rough proxy for migration processes assessment.

As further steps for accuracy enhancement of air quality assessment land cover mapping tools can be used for better understanding what happens depending on different land cover classes [22][23][24]. For further extension of air quality sensors and, in this regard, for increasing the estimations accuracy approaches from [25][26] can be used.

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