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ASSESSING TEMPORAL AND TERRITORIAL PERFORMANCE OF SDG 11 AT LOCAL SCALE

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ABSTRACT. – Assessing Temporal and Territorial Performance of SDG 11 at Local Scale. This study aims to evaluate the performance of each LAU (Local Administrative Unit) within Satu Mare County and the Satu Mare Metropolitan Area in achieving Sustainable Development Goal 11 (SDG 11) - "Sustainable Cities and Communities", for two distinct reference years: 2016 and 2024. For this purpose, a dataset was collected, based on which ten relevant indicators, identical for both years analysed, were calculated. The data were organised in a PostgreSQL database, where most of the computations were performed, including the normalisation process of the indicators. The SDG 11 Index was calculated using the normalised values, applying equal weights to each indicator. This approach enabled the assessment of the progress achieved over the past eight years towards achieving SDG 11, both at the level of Satu Mare County and the metropolitan area.

Keywords: *SDG 11, local level, PostgreSQL, Temporal analysis, Satu Mare.*

1. INTRODUCTION

In line with the 2030 Agenda for Sustainable Development, supported by the United Nations and adopted by all 193 member states, a global commitment was agreed upon to combat inequalities and injustices, eradicate poverty, and take concrete action to protect the planet. The 2030 Agenda includes 17 Sustainable Development Goals (SDGs) and 169 associated targets, which are subject to ongoing

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monitoring until the end of the reference period. This initiative provides a new perspective on how to view the world and serves as a global framework for doing things better, through clear and measurable objectives (Benedek *et al.*, 2021). It is important to assess the performance observed in progressing towards the Sustainable Development Goals, while also monitoring progress over time. Concerns regarding the measurement of progress at local and regional levels in Romania have been raised by Benedek et al. (2021), who calculated 90 sustainable development indicators at the subnational level for all 17 SDGs. Studies assessing sustainable development at the local level in Romania remain relatively scarce (Nagy, Benedek and Ivan, 2018), largely due to the lack of available data at lower administrative levels for all SDG targets. According to the study by Wang and Zhao (2025), the most extensively analysed SDGs between 2003 and 2024 were SDG 13 (Climate Action), SDG 3 (Good Health and Well-being), and SDG 11 (Sustainable Cities and Communities), which together accounted for 36% of the 21,076 articles examined.

Understanding and comparing the performance of municipalities and cities in terms of sustainable development is essential for improving quality of life, mapping spatial inequalities, and identifying problematic areas (Murphy *et al.*, 2025). Among the 17 Sustainable Development Goals, SDG 11 - Sustainable Cities and Communities – measures the level of sustainable development in urban areas and human settlements. Feng *et al.* (2023) calculated eight SDG 11 indicators and an integrated SDG 11 index for 64 cities in the Yellow River Basin, concluding that the index increased significantly in most of the cities analysed. In Japan, Yamasaki and Yamada (2022) calculated 52 SDG 11 indicators at the local level and analysed the relationships between them to identify the factors supporting progress towards SDG 11. The main challenge in assessing SDG 11 remains the lack of local-level data, particularly in rural settlements (Feng *et al.*, 2023; Khalid, Sharma and Dubey, 2020; Liu *et al.*, 2023). Methodological efforts have been made to address this data gap, such as the study conducted by Poli, Cuntò and Muccio (2024), who applied Machine Learning algorithms to predict missing values in a dataset used to compute 18 SDG 11 indicators across three regions in Italy.

This study assessed SDG 11 indicators and the corresponding composite index at the local level for two reference years: 2016 and 2024. Satu Mare County and its Metropolitan Area were selected as the case study, enabling both a spatial analysis of territorial disparities and a temporal evaluation of sustainable development trends based on ten consistently calculated indicators.

2. STUDY AREA AND DATA SOURCE

2.1. Study area

Satu Mare County is located in the northwestern part of Romania, within the North-West Development Region, near the borders with Hungary and Ukraine (fig. 1). The county comprises 59 communes, four towns (Ardud, Livada, Negrești-Oaș, and Tășnad), and two cities - Satu Mare (the county seat) and Carei.

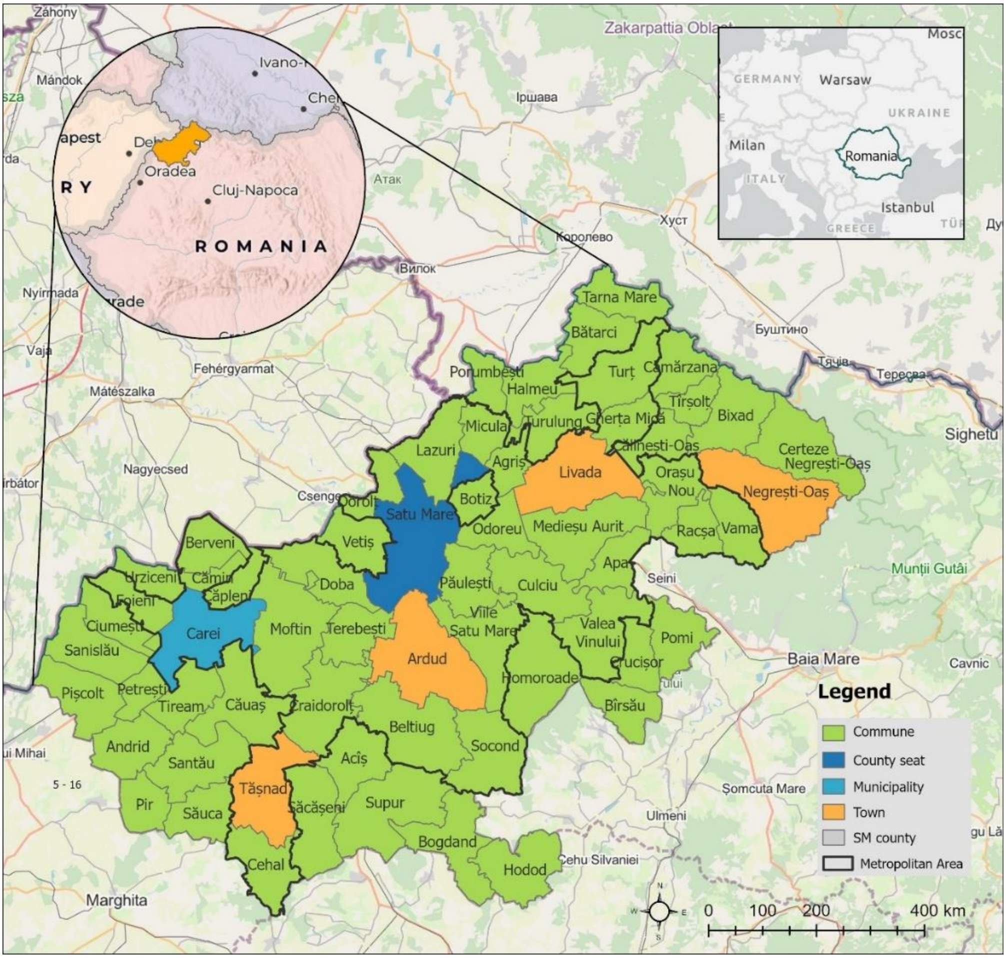

Fig. 1. Location of the study area.
Source: the authors.

The Satu Mare Metropolitan Area (SMMA) was established in 2013 and includes 31 administrative-territorial units (ATUs): the cities of Satu Mare and Carei, the towns of Livada, Tășnad, and Ardud, as well as the communes of Agriș, Apa, Beltiug, Berveni, Cămin, Cehal, Craidorolț, Culciu, Doba, Dorolț, Foieni, Gherța Mică, Lazuri, Medieșu Aurit, Moftin, Micula, Odoreu, Orașu Nou, Păulești, Racșa, Socond, Terebești, Turț, Vama, Valea Vinului, and Viile Satu Mare (SIDU, 2016). The population of the SMMA is approximately 253,592 inhabitants, of whom 112,421 reside in the city of Satu Mare (NIS, 2025).

2.2. Data source

To calculate the SDG 11 indicators (Table 1), a diverse range of data sources was employed. The first source consisted of statistical data provided by the National Institute of Statistics (NIS) for the years 2016 and 2024 (NIS, 2025). The second source included land cover datasets from the Dynamic World database (Brown *et al.*, 2022), with a spatial resolution of 10 metres, downloaded via the Google Earth Engine (GEE) platform. Based on population data from NIS and land cover information, the indicator 'Ratio of land consumption rate to population growth rate' was computed (Table 1). This indicator has also been successfully applied by Aquilino *et al.* (2020) in monitoring SDG 11 indicators at the local level in Bari, Italy. The third source consisted of data provided by the Romanian Police (GIRPTD, 2025), offering detailed records on the number of road traffic accidents and associated fatalities, serious injuries, and minor injuries for both 2016 and 2024. These accident data were spatially aggregated at the level of administrative territorial units using ArcGIS Pro.

Table 1. Summary of indicators used to construct the SDG 11 Index

SDG Indicator	Source	Normalisation
Finished dwellings (per 10000 people)	NIS	Min-Max
Population density (people per km^2)	NIS	Min-Max
Population growth rate (%) 2016-2020 and 2020-2024	NIS	Min-Max
Ratio of land consumption rate to population growth rate 2016-2023	EO and NIS	Min-Max
Living floor (m^2 per person)	NIS	Min-Max
Traffic death rate (per 1000 people)	GIRPTD	Max-Min
Serious traffic accident rate (per 1000 people)	GIRPTD	Max-Min
Slight traffic accident rate (per 1000 people)	GIRPTD	Max-Min
Traffic accidents (per 1000 people)	GIRPTD	Max-Min
Building permits (per 1000 people)	NIS	Min-Max

Source: the authors

3. METHODOLOGY

The data collected for each SDG indicator was processed and subsequently imported into a PostgreSQL database. Within this database, the ten indicators were computed separately for the two reference years, and the resulting values were then normalised on a scale from 0 to 10. Based on these normalised values, the SDG 11 index was calculated for both Satu Mare County and its Metropolitan Area. Figure 2 presents a graphical overview of the workflow, while subsections 3.1–3.3 provide a detailed description of each step in the process.

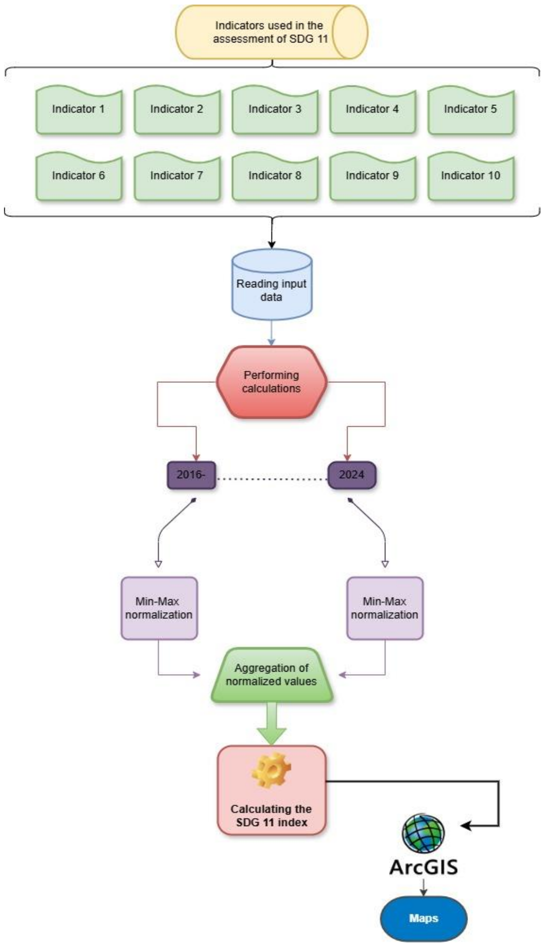

Fig. 2. Flow chart of the methodology used to calculate SDG 11.
Source: the authors.

3.1 Data processing

To calculate the indicators Finished dwellings (per 10,000 people), Population density (people per km²), Population growth rate (%) for the periods 2016–2020 and 2020–2024, Living floor area (m² per person), and Building permits (per 1,000 people), data at the local administrative unit (LAU) level were obtained from the National Institute of Statistics (NIS). Using the JOIN function, the multiple datasets required for calculating these indicators were merged into a single table. Road traffic accident data, obtained from GIRPTD, were aggregated at the LAU level and included both the total number of accidents and the number of victims: fatalities, serious injuries, and minor injuries (fig. 3).

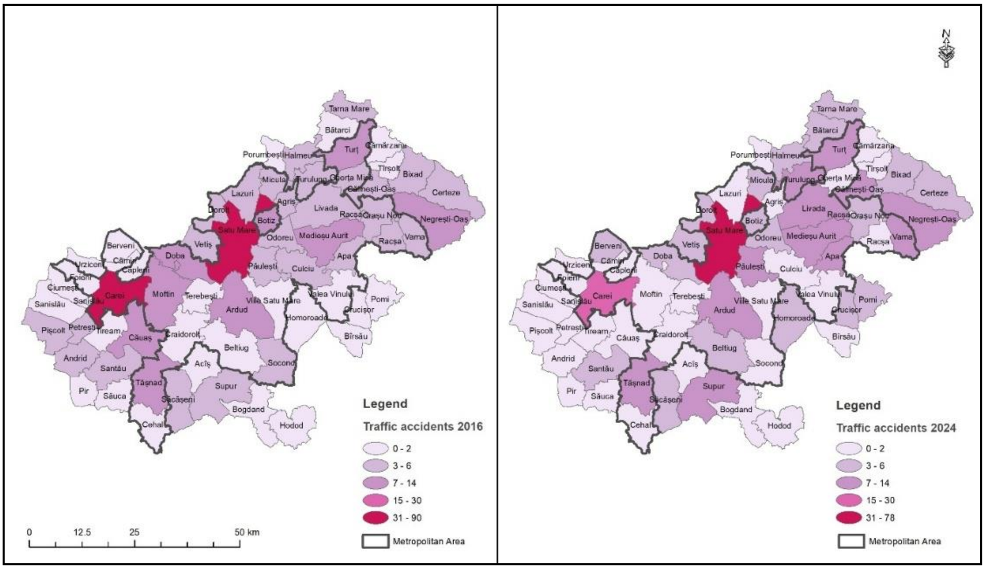

Fig. 3. Total number of accidents in Satu Mare County, 2016 and 2024.
Source: the authors.

A comparison of the two maps (fig. 3) clearly illustrates the spatial distribution of road traffic accidents within the county and the metropolitan area between 2016 and 2024. The total number of road accidents in the county decreased from 337 in 2016 to 318 in 2024, while in the Satu Mare Metropolitan Area (SMMA), the number dropped from 240 to 211 over the same period. Similarly, the number of victims in SMMA followed a downward trend: in 2016, there were 17 fatalities, 72 seriously injured, and 235 slightly injured persons, compared to 22 fatalities, 61 seriously injured, and 213 slightly injured in 2024. This evolution is most evident in the county seat, where the number of accidents decreased from 90 in

2016 to 78 in 2024, representing a reduction of approximately 13%. Although the county seat remains the primary hotspot for traffic accidents, overall road safety within the metropolitan area improved between 2016 and 2024. Nonetheless, the urban core continues to pose a high-risk zone, requiring targeted interventions to further reduce accident rates.

The SDG 11.3.1 indicator - Ratio of land consumption rate to population growth rate - was calculated for two-time intervals: 2016–2020 and 2020–2024, based on land cover data extracted from the Dynamic World database (Brown *et al.*, 2022). The land cover dataset includes nine classes (water, trees, grass, flooded vegetation, crops, shrub and scrub, built-up, bare, snow and ice), retrieved for September and October in the years 2016, 2020, and 2024 using the Google Earth Engine platform. The land cover data were then processed in ArcGIS Pro using the Tabulate Area tool, while population data for the three reference years were obtained from the National Institute of Statistics (NIS).

3.2 PostgreSQL database

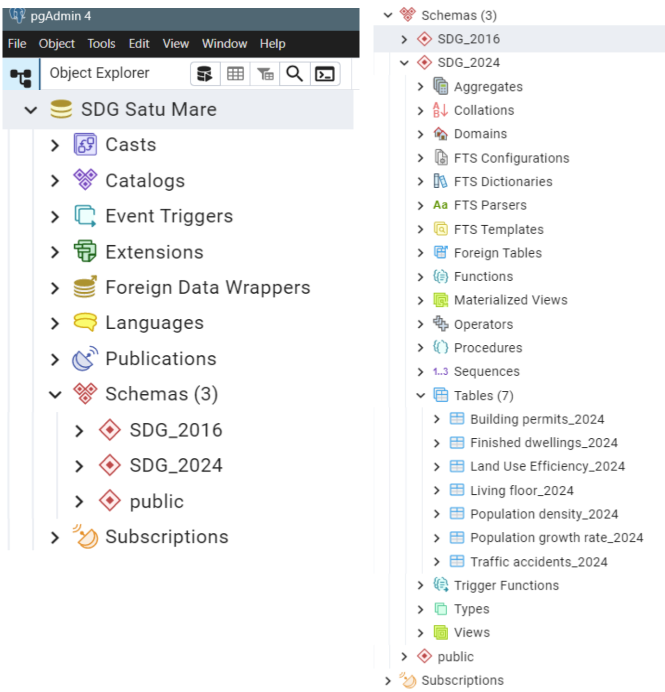

Fig. 4. Illustration of the database structure and schemas in PostgreSQL.
Source: the authors.

The locally collected data were imported into a PostgreSQL database, organised into two separate schemas - one for 2016 and the other for 2024 (Figure 4). The use of schema structures enabled the clear distinction and separate processing of data for each analysed year. As a result, information within the database could be easily queried and analysed. PostgreSQL offers the advantage of handling large volumes of data efficiently and supports fast querying capabilities, while the PostGIS extension enables the manipulation and analysis of spatial data (Haynes, Mitchell and Shook, 2020).

All ten SDG 11 indicators (table 1) were computed within the PostgreSQL database using the SQL programming language. Road traffic accident and casualty data, along with building permits, were standardised per 1,000 inhabitants, while finished dwellings were calculated per 10,000 inhabitants. Population density was expressed in people per square kilometre, and the population growth rate was calculated for two intervals: 2016–2020 and 2020–2024. The Ratio of land consumption rate to population growth rate was calculated following the UN-Habitat methodology, as the ratio between the land consumption rate (LCR) and the population growth rate (PGR). Both LCR and PGR were computed using the formulas presented below (Holobâcă *et al.*, 2022):

$$LCR_{2016} = Ln\ (Built\text{-}up_{2020} / Built\text{-}up_{2016}) / 4 \quad (1)$$
$$LCR_{2024} = Ln\ (Built\text{-}up_{2024} / Built\text{-}up_{2020}) / 4 \quad (2)$$

$$PGR_{2016} = Ln(Pop_{2020} / Pop_{2016}) / 4 \quad (3)$$
$$PGR_{2024} = Ln(Pop_{2024} / Pop_{2020}) / 4 \quad (4)$$

$$LCRPGR_{2016\text{-}2020} = LCR_{2016} / PGR_{2016} \quad (5)$$
$$LCRPGR\_{}_{2020\text{-}2024} = LCR_{2024} / PGR_{2024} \quad (6)$$

where: Built-up is the built-up space, Pop is the population, Ln - the natural logarithm, y is the number of years of the reference period, LCRPGR - Land consumption rate and population growth rate, LCR - Land Consumption Rate, PGR - Population Growth Rate.

3.3 Normalization of indicators

The SDG indicator values were normalised on a scale from 1 to 10 to ensure comparability, using both the min–max ($\hat{x}$) and max-min ($\check{x}$) normalisation methods:

$$\hat{x} = \left(\frac{x - min(x)}{max(x) - min(x)}\right) \times 10 \qquad \check{x} = \left(\frac{max(x) - x}{max(x) - min(x)}\right) \times 10$$

Where: x represents the raw data value, min(x) and max(x) define the lower and upper bounds corresponding to the weakest and best performances, respectively, while $\hat{x}$ and ($\check{x}$) denote the rescaled normalised values.

For most indicators, the min–max normalisation method was applied, where 0 represents the lowest performance and 10 the highest level of SDG achievement (Benedek *et al.*, 2021; Nagy, Benedek and Ivan, 2018). An exception was made for the indicators Traffic deaths rate, Serious traffic accidents rate, Slight traffic accidents rate, and Total traffic accidents, for which the max–min method was used, where a value of 10 corresponds to the weakest performance, and 0 to the best.

Following the normalisation of the indicators, the SDG 11 index was calculated using equal weights, meaning that each indicator contributed equally to the final value of the SDG 11 index (Sachs *et al.*, 2020; Benedek *et al.*, 2021; Schmidt-Traub *et al.*, 2017; Tomalty *et al.*, 2017). Accordingly, the SDG 11 index was computed for the years 2016 and 2024, and the results were spatially represented using ArcGIS Pro.

4. RESULTS AND DISCUSSIONS

The locally calculated SDG 11 index features standardised values ranging from 0 (the lowest level of sustainable development) to 10 (the highest level of sustainable development). In 2016, the highest sustainability score was recorded in the commune of Păulești (7.1), while in 2024, the highest score was found in the commune of Odoreu (7.6) (fig. 5). At the opposite end, the lowest score in 2016 was registered in Săcășeni (1.9), and in 2024, in the commune of Apa (3.0). These results reveal a slight upward trend in SDG 11 index values in 2024 compared to 2016 across Satu Mare County. This evolution may be attributed to the implementation of various projects over the past eight years, including infrastructure investments and the attraction of more complex development initiatives. These findings are consistent with trends reported in the literature.

For instance, Feng *et al.* (2023) remarked a significant increase in the SDG 11 index during the 2015–2020 period in the majority of the cities analysed.

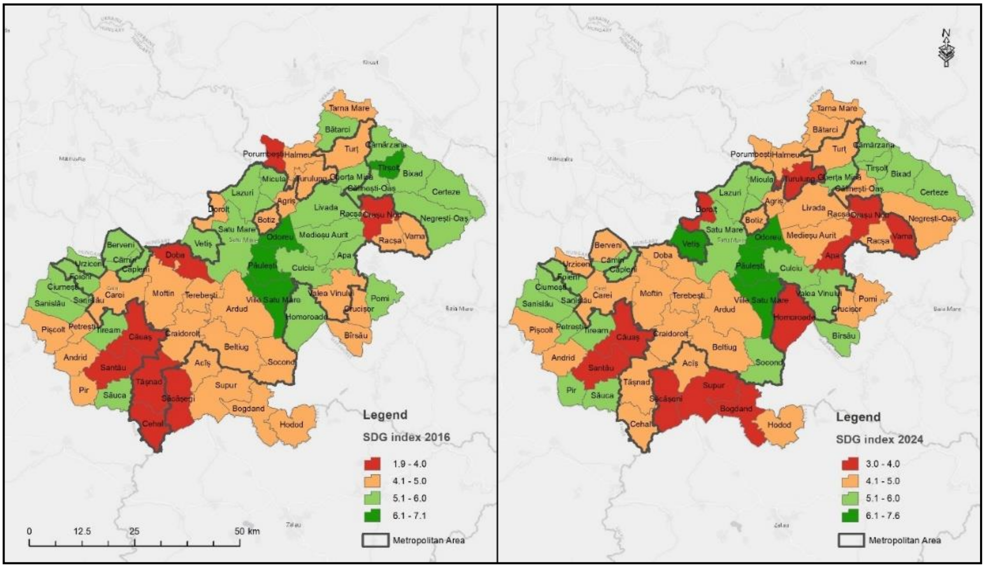

Fig. 5. SDG Index at the local level in Satu Mare County and its metropolitan area, 2016 vs. 2024.
Source: the authors.

Although the sustainable development scores were generally higher in 2024 compared to 2016, figure 5 shows that in 2016, there were 8 local administrative units (LAUs) with SDG 11 scores below 4 (Săcășeni, Căuaș, Santău, Orașu Nou, Doba, Cehal, Porumbești, and Tășnad), while in 2024, this number increased to 11 LAUs (Apa, Homoroade, Vama, Turulung, Săcășeni, Supur, Căuaș, Dorolț, Orașu Nou, Bogdand, and Santău). Among these, Săcășeni, Căuaș, and Santău located near the town of Tășnad, and Orașu Nou consistently ranked among the lowest in both periods. These communes are characterised by an ageing population and demographic decline. For instance, between 2016 and 2024, the population of Căuaș decreased by 3.8%, Săcășeni by 5.97%, Santău by approximately 4.9%, and Orașu Nou by 7.2%, according to NIS data. The economic profile of these communes is predominantly agricultural, with economies largely based on farming and limited access to essential services. Nevertheless, local administrations are making continuous efforts to modernise infrastructure and utility networks in these areas (CJ Satu Mare, 2021).

When analysing towns and cities separately (fig. 5), a decline in SDG 11 index scores can be observed with decreasing urban size. This trend highlights the need to strengthen efforts aimed at improving SDG progress in smaller towns to ensure more balanced sustainability across the county. These findings are consistent with those of Liu *et al.* (2023), who assessed SDG progress in 254 Chinese cities using open-source big data.

When examining the localities with the highest sustainable development scores (> 6), four territorial entities were identified in 2016 (Tîrșolț, Viile Satu Mare, Odoreu, and Păulești), and their positions remained generally consistent in 2024 (Păulești, Viile Satu Mare, Vetiș, and Odoreu). These peri-urban communes, located within the Satu Mare Metropolitan Area (SMMA) and close to the city of Satu Mare, are among the most dynamic and developed rural settlements in the county. According to NIS statistical data, between 2016 and 2024, the population of Odoreu increased by approximately 13%, Păulești by 12%, Vetiș by 9.8%, and Viile Satu Mare by 6.5%. Their inclusion in the SMMA, combined with the administrative capacity of local authorities, provides opportunities for attracting funding and implementing development projects. In contrast, localities more distant from the city of Satu Mare and experiencing population decline (such as Săcășeni, Căuaș, Santău, and Orașu Nou) recorded low SDG 11 index values in both years analysed.

The normalised SDG 11 indicators, calculated using the min–max and max–min methods (table 1), reveal relatively strong local performance in indicators related to the number of road traffic victims and total traffic accidents per 1,000 inhabitants, followed by the population growth rate. In contrast, the weakest performances were observed for population density, finished dwellings, and building permits. These trends remained consistent across both years analysed at the county level.

Within the Satu Mare Metropolitan Area (SMMA), the highest SDG 11 scores mirrored those recorded at the county level: in 2016, Păulești achieved an SDG index of 7.1, while in 2024, Odoreu recorded the highest score of 7.6. Conversely, the lowest level of sustainable development was recorded in 2016 in Orașu Nou (SDG index 3.3) and in 2024 in Apa (SDG index 3.0). In both Apa and Orașu Nou, agriculture remains the predominant economic activity, and both localities experienced demographic decline (approximately 2.6%). However, several complex development projects are currently being implemented, which are likely to improve their sustainable development rankings in the future. These findings indicate that the SMMA recorded both the highest and lowest SDG 11 scores within the county. In 2016, localities with SDG 11 index values below 4 included Orașu Nou, Cehal, Doba, and Tășnad - all experiencing demographic decline, except Doba. In 2024, the lowest scores were recorded in

Apa, Vama, Dorolț, and again in Orașu Nou. The highest levels of sustainable development in SMMA were consistently observed in Păulești, Viile Satu Mare, and Odoreu across both years (fig. 5). An analysis of the normalised SDG 11 indicators at the metropolitan level reveals trends similar to those at the county level, with no significant differences in performance noticed across the metropolitan area.

5. CONCLUSIONS

This study proposes the measurement, evaluation, and comparison of local-level sustainable development (SDG 11) in the period 2016-2024, based on the United Nations methodology. The performance of each rural and urban settlement in Satu Mare County was quantified using a diverse range of data sources, including Earth Observation data. All SDG 11 indicators and datasets were stored and processed within a PostgreSQL database. The results revealed higher SDG 11 scores in the peri-urban areas of Satu Mare municipality, particularly in the most dynamic communes of the county - Păulești, Viile Satu Mare, Vetiș, and Odoreu - which consistently ranked highest in both analysed years. Conversely, the lowest levels of sustainable development (SDG 11) were recorded in the communes of Săcășeni, Căuaș, Santău, and Orașu Nou - areas characterised by population decline, ageing demographics, and agriculture-based economies.

The results of the study will enhance the capacity of local administrations to identify the necessary levers for improving the level of sustainable development in localities facing demographic decline and low SDG 11 scores. Furthermore, the findings will contribute to a more balanced, sustainable development across the county, help reduce territorial disparities, and support local authorities in formulating robust local development strategies.

Disclaimer: This paper has been edited using the ChatGPT model 4.5 (ChatGPT Plus) to improve fluency, clarity, and readability. All content, ideas, analysis, and conclusions are the sole work of the authors.

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