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Original Research

Analysis of the Sustainable Development Goal 3 index for Italian municipalities

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ABSTRACT

Objectives: Improving health at global and local scales is one of the 17 Sustainable Development Goals (SDGs) set by the United Nations (UN) for the period 2015–2030, specifically defined by SDG3, which includes 13 targets described by 28 indicators. In this context, the aim of the current study was to propose a protocol to infer SDG3 values at municipality level with the current openly available data.
Study design: The study incorporated a quantitative research.
Methods: To calculate the SDG3 index, defined as the average of all 13 target scores, official Italian data at five geographical granularities covering the period 2018–2022 were used, and a spatial downscaling strategy was implemented. The quality of matching between original and inferred indicators was assessed applying a specific standard (International Organisation for Standardisation [ISO]/TS 21564) that matches quality between terminology resources with regards to health care. The significance of regional/provincial differences was assessed by the Kruskal–Wallis test with Bonferroni correction, and the Moran's index with queen contiguity method was applied to evaluate clustering tendency.
Results: The geographical distribution of scores varied considerably (and with statistical significance) across the targets, with municipalities in the central part of the country achieving relatively good overall performance. Matching quality also varied consistently across targets. Clustering tendency was observed and was likely due to regional differences in data collection protocols.
Conclusions: The SDG3 index, as an internationally standardised measure of health, can be used to validate urban health indices; however, considerable improvement by official data providers in Italy is required to guarantee access to data at the municipal level.

Introduction

Urban indices represent a valuable tool in highlighting inequalities among municipalities and consequently identifying geographical areas where substantial action is required. In this context, many complex urban health indices (UHIs) have been proposed in the literature, and their five main purposes have been defined as follows: (i) informing policy and decision-making; (ii) monitoring and evaluation; (iii) research; (iv) benchmarking; and (v) communication with non-specialists. Most previous studies have focussed on the first category (i.e., informing policy and decision-making).[1,2] Additionally, several attempts to provide a standardised set of indicators for the construction of an UHI were made by organisations such as the United Nations (UN), the United States Department of Health and Human Services, the World Bank, and the World Health Organization (WHO),[3] with the latter also proposing the calculation of a specific index called the Urban Health Index.[4] However, no universally recognised standard exists, neither for the indicators nor for the methods used for the computation of UHIs; as a result, existing indices are characterised by a large heterogeneity in these terms. Moreover, the lack of validation is a very diffused limitation in the development and use of such UHIs.[1,5,6]

Since the establishment of the Sustainable Development Goals (SDGs) by the UN on 1st January 2016, multiple studies have been developed with the purpose of assessing the current progress towards their achievement.[7–10] Additionally, in 2012, the UN established the Sustainable Development Solutions Network (SDSN) to foster innovation and collaboration towards achieving the SDGs at global and local levels.[11] The SDSN contributes to this aim by

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publishing the Sustainable Development Report, which provides an overview of the total progress in all 17 SDGs across 166 countries. In its most recent version,[12] Italy was classified as the 24th among the 166 countries, preceded by 22 European states and Japan. However, when accounting for the spillover effect, measuring the environmental and social impact of actions within each country on the economy of other countries, Italy's ranking shifted to 127/166, with only six European Union members characterised by a more positive global spillover effect.

SGD3 (i.e., to “Ensure healthy lives and promote well-being for all at all ages”) is described through 13 targets including 28 indicators, addressing various factors relevant to public health access, non-communicable and communicable diseases, maternal and child health, risk factors prevalence, and health financing and research. According to the Sustainable Development Report,[12] Italy's progress towards SDG3 is described as ‘moderately improving’, yet ‘challenges remain’. Within SDG3 for Italy, one of three indicators showing no progress is the “Gap in life expectancy at birth among regions”, highlighting considerable local disparities, thus making Italy an interesting case study. Existing empirical analyses on SDGs in Italy have attempted to address this challenge by focussing on provincial level as the smallest geographical unit; however, they only covered a subset of targets and/or indicators. In a recent study,[13] the current authors initially proposed a methodology for calculating an SDG3 index at the municipal level applied to one region of Italy (i.e., Lombardy) as a pilot study, to potentially offer a more granular perspective towards achieving SDG3.

Considering the aforementioned research gaps, both in relation to SDG3 and more broadly to UHIs, the aim of the current study was to extend the methodology to propose and compute an index based on SDG3 targets at municipal level for the whole Italy. In order to enhance its reproducibility, only official open data were used. The main objectives of this index were the following: (i) to overcome the challenges in constructing an UHI covering an entire country, ultimately providing a standardised measure to validate other spatial analyses of health status and (ii) to provide an overview of the current spatial distribution in the level of achievement of SDG3 goals in Italy and to highlight possible geographical disparities along the territory through statistical comparison. Regardless of the specific study case, this work is relevant to international research as it proposes original methodological solutions to overcome the challenges posed by limited data availability and insufficient geographical granularity, which represent very common issues when addressing the country-wise computation of UHIs and, in particular, SDG3 assessment at the municipality level.

Methods

Study areas and study design

Italy is the 10th largest country on the European continent, with an area of more than 300,000 km^2 and a population of nearly 60 million. As of 1st January 2023, Italy is administratively divided into 20 regions, 107 provinces (including two autonomous provinces), and 7901 municipalities (see Figure S1 in the supplementary material). For statistical purposes, the following classification of municipalities has been defined by the Italian National Institute of Statistics (Istat): 12 municipalities in the centre of the metropolitan area (Turin [Piedmont region], Milan [Lombardy], Venice [Veneto], Genoa [Liguria], Bologna [Emilia-Romagna], Florence [Tuscany], Rome [Lazio], Naples [Campania], Bari [Apulia], Palermo [Sicily], Catania [Sicily], Cagliari [Sardinia]); 1051 municipalities located in the same provinces as the aforementioned metropolitan areas, constituting 13.3% of all Italian municipalities; 3253 municipalities with up to 2000 residents (41.2%); 2755 municipalities with 2001–10,000 residents (34.9%); 733 municipalities with 10,001–50,000 residents (9.3%); and 97 municipalities with more than 50,000 residents (1.2%).

Fig. 1 illustrates the geographical distribution of the aforementioned categories, whereas Table S1 provides additional details on the largest municipalities in the centre of the metropolitan areas and on the largest provinces within these areas. According to this classification, almost one in five Italians lives in a municipality with 10,001–50,000 residents, making this class the most populated one nationwide. Among both the centres and the provinces of the metropolitan areas, Rome emerges as the most populated, followed by Milan and Naples. In terms of land area, aside from the municipality of Rome and its province, the municipalities of Venice and Genoa rank among the top three largest centres, whereas the provinces of Turin and Palermo place among the top three largest provinces.

This is a quantitative study in which diverse numerical methods were used to transform raw data, assess their representativeness, calculate the SDG3 index, and conduct subsequent statistical analyses. Methods included data preprocessing techniques, mathematical computations to derive the index, and statistical analyses to evaluate geographical patterns and clustering tendencies. All the implemented computations are described in detail in the following sections.

SDG3 data sources

To develop the SDG3 index, as a first step, the indicators of each of the 13 SDG3 targets, officially defined by the WHO, were matched to available open data, published by Istat, the Ministry of Health and the Italian National Institute of Health (i.e., Istituto Superiore di Sanità), henceforth referred to as ‘Italian indicators’. The process resulted in matching the Italian indicators with official indicators, except for the following: four cases in which multiple Italian indicators were assigned to one official indicator because the latter was specified with finer details (by age group [3.7.2] or by disease [3.4.1]) or because it was too generic in its description (3.8.1 and 3.c.1); eight cases in which the official indicator (3.3.1, 3.5.2, 3.7.2, 3.8.1, 3.8.2, 3.a.1, 3.b.2, 3.c.1) was matched to a proxy, due to lack of specific available data among the Italian indicators; and 11 cases in which no Italian indicator was assigned to an official one (3.1.1, 3.1.2, 3.3.3, 3.3.5, 3.5.1, 3.7.1, 3.9.1, 3.9.2, 3.b.3, 3.d.1, 3.d.2) due to lack of data.

Data were available for 11 out of 13 official SDG3 targets. In Table S2, for each SDG3 target and indicator, the corresponding Italian indicator is reported, together with the relevant source, the latest temporal update, and the most detailed spatial level available.

Furthermore, the International Organisation for Standardisation (ISO) developed the ISO/TS 21564:2019 standard to ensure consistency and clarity in communication among stakeholders involved in healthcare management and policymaking.[14] Therefore, to obtain a measure of the matching quality between terminology resources in the official and in the Italian indicator, the ISO/TS 21564:2019 standard was applied, where matching was defined into four possible levels:[14] 0 = exact match on semantic domain; 1 = fully inclusive overlap of semantic domain; 2 = non-inclusive overlap of semantic domain; and 3 = no overlap.

SDG3 index computation

When formulating a municipal index, if data on the Italian indicators were available at a less detailed spatial level (i.e., provincial, regional, or in bigger areas), the same value was assigned to all the municipalities being part of such geographical partition, unless they were separately reported for the different classes of

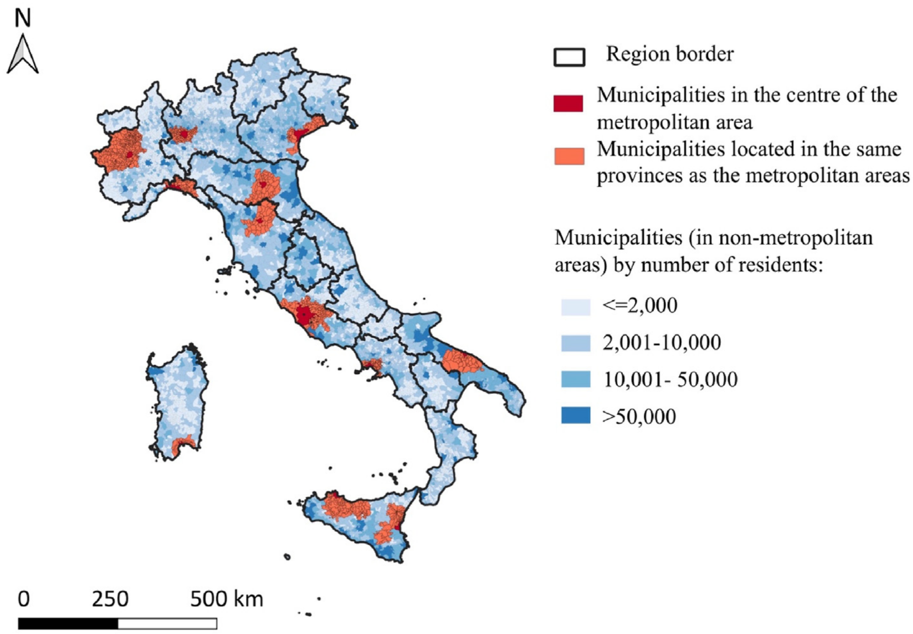

Fig. 1. Geographical distribution of classes of municipalities defined by the Italian National Institute of Statistics (Istat).

municipalities (see Fig. 1). In this case, an original mathematical approach was proposed; namely, the final value was computed as the baseline value, corresponding to the municipality class, weighted by a coefficient calculated as follows:

$$coefficient = \frac{value_a * number\ of\ municipalities_a}{\sum(value_b * number\ of\ municipalities_{b\ within\ a})}, \quad (1)$$

where 'a' is the less detailed geographical partition and 'b' is the class of municipality.

For example, in the Lazio region, the distribution of the 378 municipalities in the six classes resulted in 1, 120, 121, 101, 32, 3. Assuming an Italian indicator (% of smokers in 2022) measuring 0.205 for the whole region, and baseline values of 0.185, 0.214, 0.188, 0.188, 0.192, and 0.209 for each of the classes, respectively, the regional coefficient for Lazio is equal to

$$coefficient = \frac{0.205 * 378}{0.185 * 1 + 0.214 * 120 + 0.188 * 121 + 0.188 * 101 + 0.192 * 32 + 0.209 * 3} = 1.04 \quad (2)$$

Accordingly, for each of the 378 municipalities in Lazio, the baseline value corresponding to its class, weighted by 1.04, was assigned.

For each Italian indicator, once having derived the values for each municipality, data were normalised between 0 and 1, with 0 representing values relevant to poor health outcomes and 1 being the best outcome.

Regarding the calculation of scores relevant to each official indicator and target, if multiple Italian indicators were used together for the computation of one official indicator, they were averaged to compute the unique output, according to equation (3):

$$official\ indicator\ score = \frac{\sum_i^n Italian\ indicator_i}{n}, \quad (3)$$

where 'n' is the total number of Italian indicators forming the official indicator.

Similarly, the score of each target was then calculated as the average of the official indicators' scores included in it (equation (4)):

$$target\ score = \frac{\sum_j^m official\ indicator_j}{m}, \quad (4)$$

where 'm' is the total number of official indicators forming the SDG3 target.

To compute the final SDG3 index, as no specific guidelines for weighting were provided by the UN, the output value was defined as the average of all the available targets (equation (5)), an approach widely adopted in relevant literature,[15,16] including in particular the SDSN Sustainable Development Report:[12]

$$SDG3\ index = \frac{\sum_k^l target_k}{l}, \quad (5)$$

where 'k' is the total number of SDG3 targets.

As a result, the final index ranges from 0 to 1, with higher values corresponding to a greater fulfilment of the SDG3 targets in the corresponding municipality. The workflow of the index computation is graphically summarised in Fig. 2.

Statistical analysis and visualisation

Data were summarised using descriptive statistics (i.e., mean, population-weighted mean, standard deviation, minimum, 25th percentile, median, 75th percentile, maximum). Additionally, the Kolmogorov–Smirnov test was applied to evaluate whether data followed a normal distribution. Subsequently, the Kruskal–Wallis test with Bonferroni correction was performed to determine if the final index for all regions, and for all provinces within each region, originated from the same distributions.

The legends on the maps describing quantitative outcomes were constructed using the quantiles method, ensuring an equal distribution of municipalities across each class, with a total of five or 10 classes set arbitrarily. In case this method led to a poor visualisation due to the values' distribution, the Jenks natural breaks method[17] was used.

To analyse the clustering tendency of the final SDG3 index, and of the three targets composed entirely of the Italian indicators with original data provided directly at the municipal level, Moran's index (both global and local) with the queen contiguity method[18] to define neighbours was applied. The resulting significant associations (significance level equal to 0.05), based on the presence of local spatial autocorrelation among municipalities, were visualised as a map of four categories (results reported in Fig. 5): high-high (a municipality with a high score surrounded by the municipalities yielding high mean of scores); low-low (a municipality with a low score surrounded by municipalities yielding low mean of scores); low-high (a municipality with a low score surrounded by municipalities yielding high mean of scores); and high-low (a municipality with a high score surrounded by municipalities yielding low mean of scores).

Results

The SDG3 index was calculated for the Italian municipalities existing at the 1st January 2023, excluding Misiliscemi, in Sicily region, formerly part of Trapani municipality, as the computation of indicator values was not possible (the municipality was created by disaggregating a district in the city). Therefore, the proposed index was computed for a total of 7900 municipalities.

Matching between SDG3 official indicators and Italian indicators

Based on the ISO/TS 21564:2019, for 11 of the 28 official SDG3 indicators, no corresponding Italian indicator was found (level 3), as presented in Table S2. For the remaining 17 official indicators, 29 Italian indicators were matched, of which 11 represented an exact match on semantic domain (quality level 0), whereas nine indicators were assigned a quality level of 1, and nine indicators a quality level of 2. The resulting quality of the matching process for each Italian indicator to each SDG3 official indicator is summarised in Figure S2.

A description of the basic statistical properties of the raw values (i.e., values assigned to each municipality) for the 29 Italian indicators is summarised in Table S3. The distribution of all Italian indicators after normalisation and ranking (i.e., value 0 corresponding to the poorest health performance and value 1 to the best performance), and that of the SDG3 targets (calculated according to equation (4)), is graphically presented in Fig. 3 as boxplots of the values obtained for the 7900 municipalities.

The characteristics of indicators' distribution are reflected in the boxplots of each SDG3 target (bottom panel of Fig. 3). In particular, four targets (i.e., 3.4, 3.6, 3.9, 3.b) showed relatively narrow interquartile ranges and a large number of outliers, with the first three composed entirely of mortality rates provided at municipal level. Of all 11 normalised and ranked targets, only four (i.e., 3.3, 3.8, 3.b, 3.c) had a median value below 0.5; among the remaining targets, the lowest median was 0.59 (target 3.5).

SDG3 index for Italian municipalities

The values of the final index (i.e., the average of all available targets' scores) ranged from 0.595 to 0.81. The smallest value was reached by Terragnolo in the province of Trento (Trentino-Alto Adige/Südtirol region), with a population of 707, and the greatest by Girasole in the province of Nuoro (Sardinia region), with a

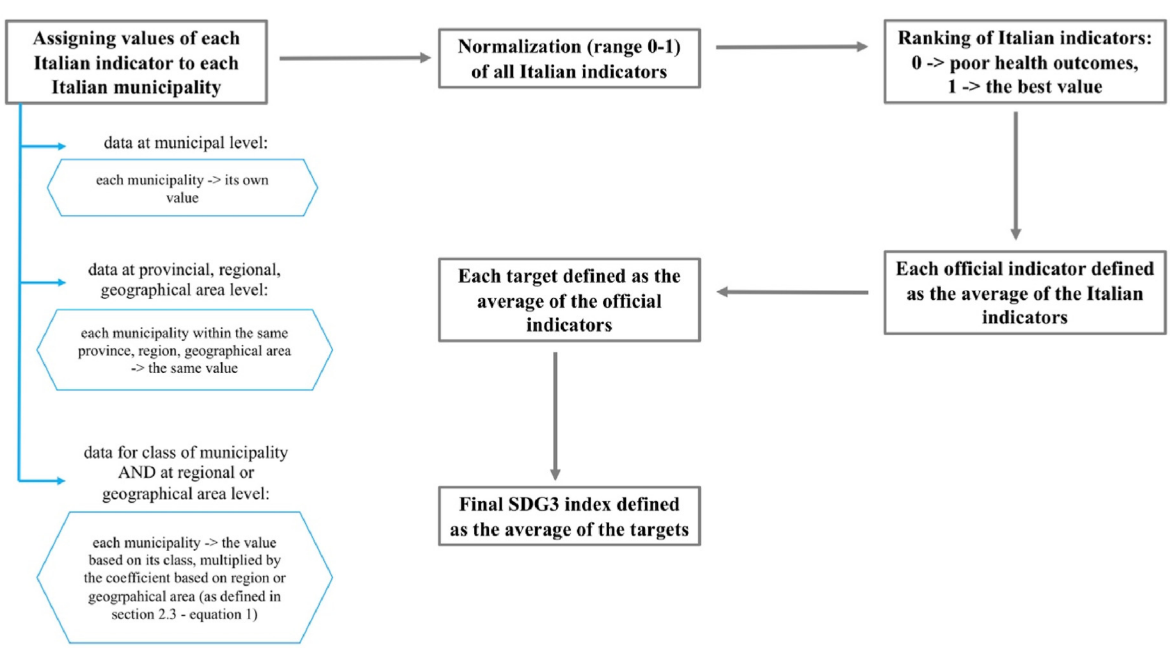

Fig. 2. Workflow of SDG3 index computation for the Italian municipalities. Abbreviation: SDG = Sustainable Development Goal.

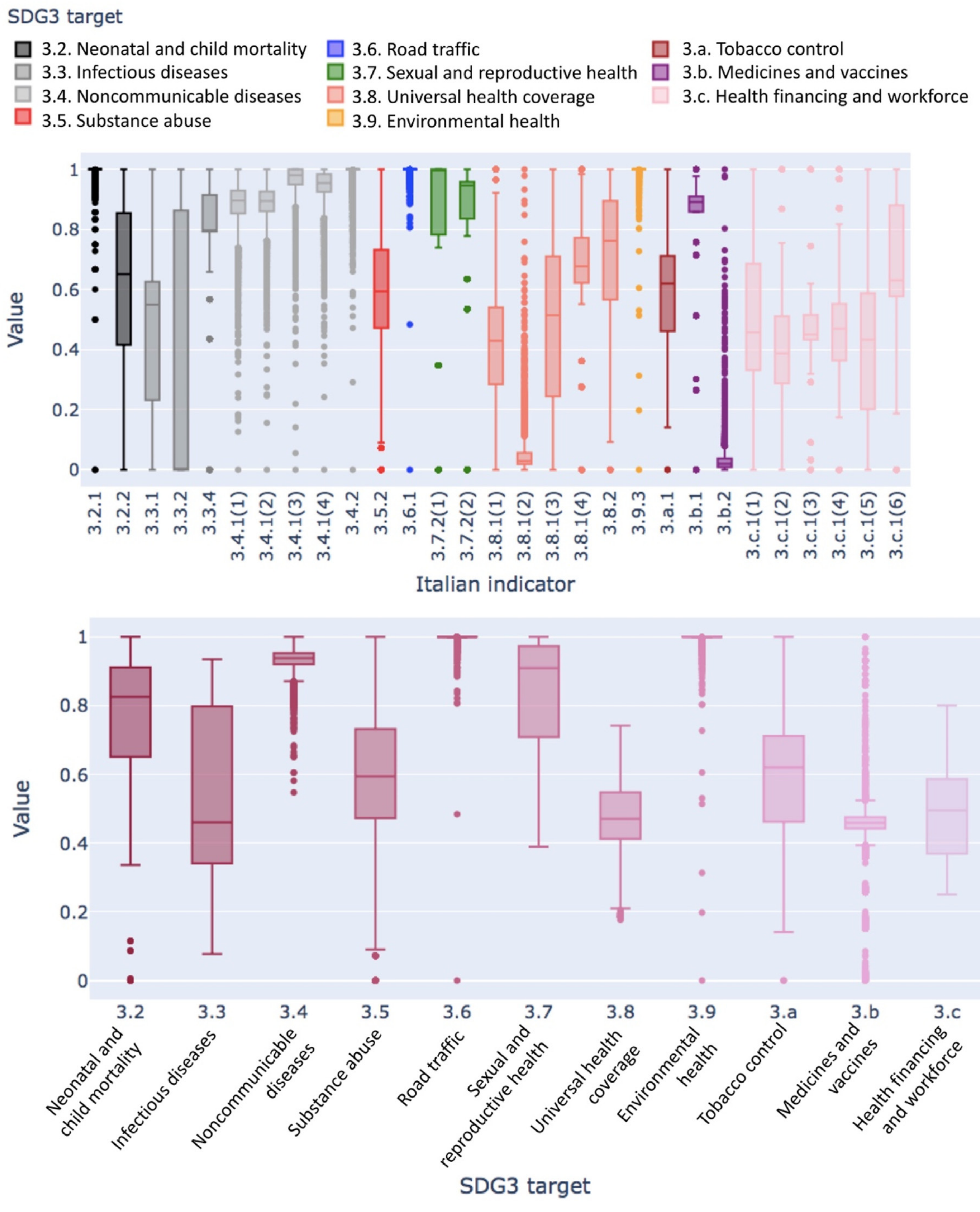

Fig. 3. Top panel: Boxplots of the considered 29 Italian indicators after normalisation and ranking, as described in section 2.3. Bottom panel: Boxplots of the 11 SDG3 targets (i.e., the average of official indicators as described in equation (4) in section 2.3). Abbreviation: SDG = Sustainable Development Goal.

population of 1350. The median value of the index was 0.697 (25th–75th percentiles = 0.681–0.719). When considering classes of municipalities, the greatest median value was achieved by municipalities in the centre of metropolitan areas (0.709), which was closely followed by municipalities with up to 2000 residents (0.707), followed by those with between 10,001 and 50,000 inhabitants (0.698), municipalities in the province of the centres of the metropolitan areas (0.691), municipalities with between 2001 and 10,000 inhabitants (0.690), whereas the lowest score was achieved by those with a population of more than 50,000 (0.683).

The computed final index for each municipality is visualised as colour-coded information in Fig. 4 (legend of categories obtained with quantiles method) for the whole country and in Figure S3 for each region separately.

At the regional level, the largest population-weighted mean of the SDG3 index was obtained for Sardinia (0.775), Molise (0.737), and Piedmont (0.721), whereas the smallest for the autonomous province of Trento (0.635), of Bolzano (0.637), and for Sicily (0.667). The same order was also reflected in the distribution of index's median across regions. The largest min–max range within the same region was noted for Piedmont (0.154), Marche (0.131), and Abruzzo (0.092). In general, municipalities located in the central, far North-East and far North-West regions of Italy reached relatively large values. The boxplots of the SDG3 index at the regional level are plotted in Figure S4.

The global Moran's index (gMI) for the SDG3 index showed a strong tendency to cluster within the Italian territory, with a value of gMI = 0.91 against the expected gMI = $-1.3*10^{-4}$. Regarding the three targets with municipal granularity (i.e., 3.4, 3.6, 3.9), the outcome was significant only for target 3.4. Non-communicable diseases showed a small tendency to cluster (gMI = 0.16). The four types of spatial autocorrelation deriving from local Moran's index for the final SDG3 index and for target 3.4 are plotted in Fig. 5.

Scores of single targets are presented in Figures S5–S7. Based on the geographical distribution of the resulting values of the 11 SDG3 targets, it was possible to identify three groups:

1. G1—high scores in northern municipalities, low scores in southern municipalities: 3.7 Sexual and reproductive health, 3.8 Universal health coverage, 3.b Medicines and vaccines.
2. G2—low scores in northern municipalities, high scores in southern municipalities: 3.3 Infectious diseases, 3.5 Substance abuse.
3. G3—No clear geographical trend: 3.2 Neonatal and child mortality, 3.4 Non-communicable diseases, 3.6 Road traffic, 3.9 Environmental health, 3.a Tobacco control, 3.c Health financing and workforce.

The standard deviation across all targets' scores ranged from 0.192 in Alice Bel Colle (Piedmont region) to 0.391 in Bresimo (Trentino-Alto Adige/Südtirol region). The standard deviation for each Italian municipality is plotted in Figure S8.

Both the final SDG3 index and the target scores were not normally distributed. Therefore, the municipal scores across regions and across provinces in the same region were statistically compared using the Kruskal–Wallis test. The municipal scores were differently distributed among regions with statistical significance, both for single targets and for the final index. The analysis of spatial patterns across provinces within each region was limited to the final SDG3 index, as the geographical granularity of the data hindered the analysis of each target separately. The only regions where the distribution of the municipal index did not vary across provinces were Trentino-Alto Adige/Südtirol and Abruzzo.

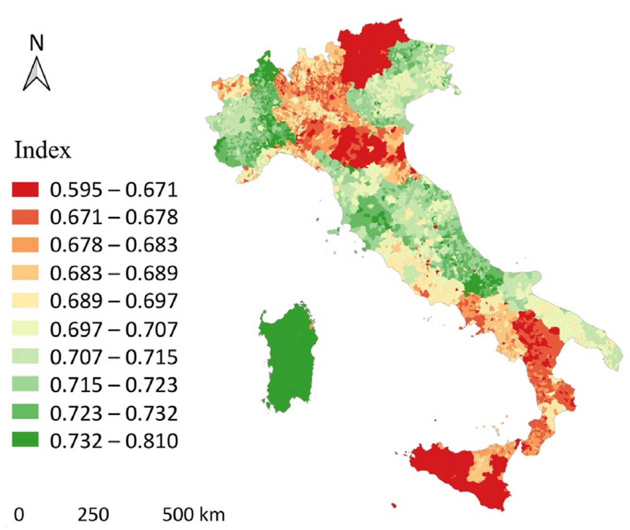

Fig. 4. Final SDG3 index computed for all the 7900 Italian municipalities. Abbreviation: SDG = Sustainable Development Goal.

Discussion

In this study, an index based on SDG3 was developed and applied at the granularity level of the 7900 Italian municipalities. To do so, open data relevant to 29 Italian indicators at either municipal, provincial, regional, population-based municipality class or geographic area level were utilised and matched to 11 out of the 13 SDG3 targets. To the best of the authors' knowledge, this is the first attempt to provide an SDG3 index based on open data at the municipal level for a whole country, using a standardised measure to assess the quality of the matching between officially defined indicators and available equivalents.

The statistical properties of the resulting indicators varied significantly and, consequently, the geographical distribution of the scores relevant to the SDG3 targets was heterogeneous. In general, the computed SDG3 index values indicated that municipalities in the central portion of Italy were characterised by a relatively good fulfilment of SDG3. The significant differences in the score's distribution, even across provinces of the same region, emphasise the need to conduct the SDG analyses at a detailed geographical level.

Several general problems with regard to the formulation of the SDG3 index were encountered for Italy, and also possibly relevant for other countries, as described in detail in a preliminary analysis,[13] including the following: the definition of the SDGs (some targets lack clarity on the information to be considered, as indicators are vaguely defined); information robustness and spatial representativeness (for certain indicators, there was a lack of administrative standardisation, and self-reported data can potentially be inaccurate); fluidity of the goals (the 13 SDGs are interconnected, not only synergistically but also with some trade-offs); and quantitative measurement (while the SDGs are expected to be achieved by 2030, only two SDG3 targets have specific quantitative objectives). The lack of numerical outcomes for most SDG3 targets suggests the need to consider periodic changes in scores rather than a fixed index.

Comparison of the Italian results with the literature

Since the establishment of the SDGs, various studies have been conducted to measure progress towards SDG3 (or its single targets/indicators), mostly focussing on wide national or international geographical areas, such as Organisation for Economic Co-operation countries,[19] the least developed Asian countries,[20] South Asia and Sub-Saharan Africa,[21] or Latin America.[22] In Italy, one study discussed state-of-the-art SDG index development,[23] whereas another one analysed the contribution of the Italian National Healthcare System to the achievement of SDG3.[24] Additionally, six studies developed and proposed national SDG indices, including SDG3, with four of them providing it for the capital cities of each province,[25–28] whereas the remaining two were focussed on the regional[29] or macro-area scale.[30]

Focussing on single indicators that constitute SDG3 targets, five articles in which they are explicitly defined were available, with each of them covering different sets. The smallest study accounted for five indicators only,[25] among which three were identical to those officially defined for SDG3. Two other studies accounted for one additional indicator, aligned[27] or not[28] with the official indicators. A single study,[30] comparing the performance of Italy and Spain on macro-area divisions, defined SDG3 as a set of nine indicators, either corresponding to or proxying five official targets. Finally, one study by D'Adamo et al.[29] matched 28 Italian indicators to 11 official targets, thus closely aligning with the approach of the current study. The main difference with the present work is represented by the geographical granularity, as D'Adamo et al. computed and reported the results at the regional level, whereas the current study aimed at a municipal granularity that had never been reported previously. Additionally, the current study assessed the matching quality of indicators through an official standard (ISO/TS 21564).

With regards to the spatial perspective, two studies,[28,29] with a large difference in the number of included indicators, generated maps for SDG3 scores. Interestingly, although all indicators referred to the same SDG3, substantial discrepancies were observed in the geographical distribution of the performance scores reported for single targets, in particular, internally to the northern regions (i.e., Piedmont, Trentino-Alto Adige/Südtirol and Liguria). Similar evidence emerged from the present study (see Figures S5-S8), with the standard deviation of targets' scores exceeding 0.3 for selected northern municipalities. Moreover, a previous mapping of the results at the provincial level[28] revealed important score variations within regions, in agreement with the current results, as confirmed by the statistical tests. This strong spatial variability strengthens the need to conduct SDG3 analyses at a more detailed geographical level. Non-etheless, some clear trends in line with the current study findings have emerged—the central areas of Italy demonstrated relatively strong performance for the final SDG3 indicator, whereas the south achieved the lowest scores.

Several studies have quantitatively assessed the differences in various health, social, and economic indicators across Italian regions, particularly focussing on the North–South gap.[31–36] Notably, since the 1990s, the Italian National Health Service has been regionalised, thus potentially contributing to the spatial differences in SDG3 scores. A previous study determined that this regionalisation has further widened the already existing North–South gap in terms of residents' satisfaction with regional hospital services, patients' regional mobility, and regional healthcare deficits.[32] Additionally, another study on Italian data found a significant correlation (r = 0.936) between intelligence quotient (IQ) and geographical latitude, suggesting genetic admixture with populations that immigrated from the Near East and North Africa as a possible cause.[33] Furthermore, regional IQ showed a significant negative correlation with infant mortality and a positive correlation with income level.[33] The financial dimension was also identified as a factor influencing regional inequalities in actual versus necessary spending on health care.[34] Southern, poorer regions are favoured in terms of publicly paid pharmaceuticals and medical visits, whereas richer regions in the North benefit more in terms of residential and hospital care.[34] Beyond the North–South gap in the health sector, a recent study also highlighted considerable differences among regions in the North-East, North-West, and centre of Italy in terms of disease prevention, community health services, and hospitals,[35] which is in agreement with the current study results. In addition to the regionalisation of the public health system, the COVID-19 pandemic was also cited as a possible cause for these disparities.[35,36]

Therefore, the existing spatial disparities in economic, social, and educational factors, along with the regionalisation of the national health system, could be identified as the main drivers of the spatial differences in SDG3 targets found in this study. Despite considerable policy efforts towards SDGs' achievement, that encompass, among others, accounting for the SDGs in the national budget document, issuing an official governmental statement endorsing the implementation of the SDGs, and formulation of a lead government unit for the coordination and implementation of the SDGs across ministries,[12] there is an important need for regional policy coordination.

Municipal SDG3 as an urban health index

Several UHIs, not based on SDG3, have been developed since the early 20th century.[2,5,6,37–55] To understand the underlying health components, different techniques were proposed, including principal component or factor analysis, regression, expert opinions, or

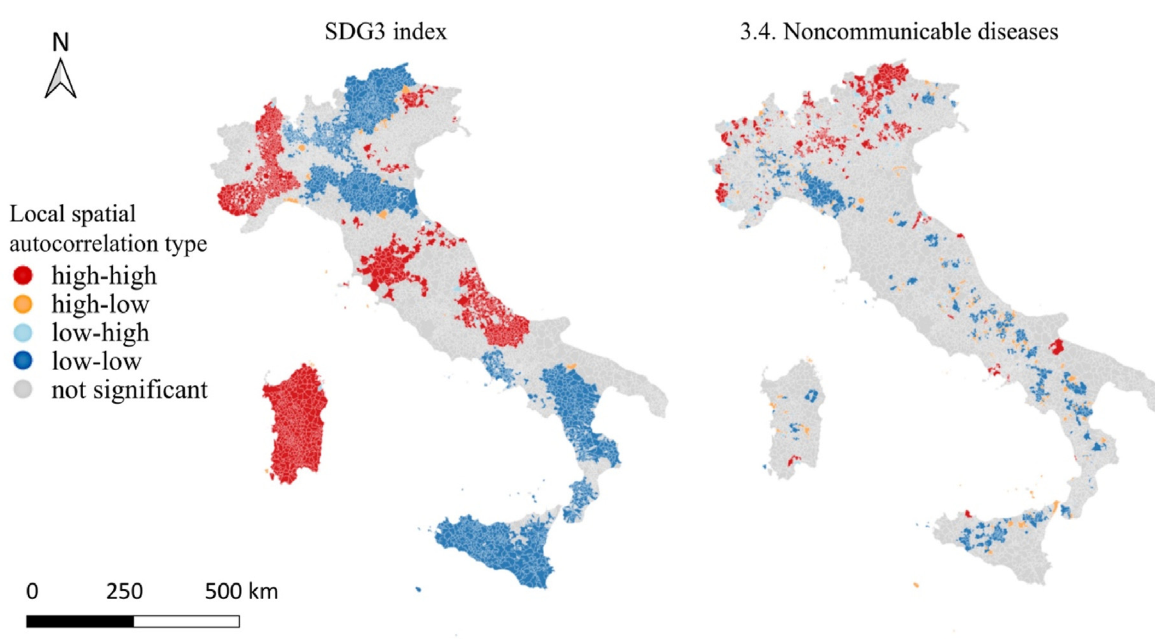

Fig. 5. Final SDG3 index and target 3.4. Non-communicable diseases spatial autocorrelation types (from local Moran's index). High-high: a municipality with high score surrounded by the municipalities yielding high mean of scores; low-low: a municipality with low score surrounded by municipalities yielding low mean of scores; low-high: a municipality with low score surrounded by municipalities yielding high mean of scores; high-low: a municipality with high score surrounded by municipalities yielding low mean of scores. Abbreviation: SDG = Sustainable Development Goal.

entropy. For the SDG3 index, a complex data-processing approach was not necessary, as the indicators were pre-defined, thereby making equal weighting appropriate. This approach might, however, hinder the reliability of results in countries where a consistent variability characterises the distribution of the indicators composing the same target, as emerged for some of the targets in Italy.

Among the previously developed health indices, none considered the existing limits imposed by the regulations in a quantitative perspective, such as the numerical distance of pollution concentration from air-quality thresholds. Similarly, the SDG3 targets are characterised by the lack of quantitatively defined objectives. Therefore, an index based on SDG3 can only be used for comparison among geographical units, but it is not representative of the distance from the actual fulfilment of SDG3 objectives.

Previous studies have repeatedly identified a lack of national coverage at a more detailed level as a limitation, further highlighted by the possible variation in relationships among urban, village, and rural areas. In the current study, only 10 out of 29 indicators could be inferred by data sources provided at the municipal level; as a consequence, it is not surprising that the Moran's index indicated a tendency to cluster, with the clusters mostly corresponding to provincial or regional borders, as observed in Fig. 5. This conclusion is corroborated by the fact that no correspondence with administrative boundaries could be observed for the target inferred from data that were fully provided at the municipal scale. Another common limitation of the aforementioned UHI, potentially overcome by the SDG3 index, was the impossibility to validate the results, with over half of them not being evaluated against any official health data. In contrast, an SDG3 index, such as the one the developed in this study, represents a worldwide standardised measure of health status and, as such, could potentially be set as the gold standard to validate other health indices, thus enabling a more comprehensive analysis of national health interdependencies.

Conclusions

To the best of the authors' knowledge, this is the first attempt to propose a reproducible SDG3 index based on open data, computed at the municipal level, covering the whole territory of a country, specifically Italy in this case. This index enlightened disparities in Italy's current sustainable health status, thus potentially enabling local policymakers to use it to comparatively evaluate the territorial performance in terms of adoption of policies towards the fulfilment of SDG3 goals and to identify areas that require substantial action. We highlighted the importance of calculating indices at the local level, as the results significantly varied at high geographical granularity. Also, the proposed methodology could be applied for longitudinal analysis using available data to assess municipal improvements over time. However, one of the major challenges identified in advancing towards monitoring SDG3 achievement in Italy is the lack of data, compounded by their insufficient temporal and spatial granularity. This deficiency hinders the ability to conduct comprehensive statistical analyses, which are crucial for identifying specific areas where targeted actions are necessary. Non-etheless, the current study could provide valuable insights to guide local decision-makers in developing and implementing targeted strategies, thereby serving as a call to action for effective policymaking.

This work holds global significance in addressing the methodological difficulties associated with data limitations at the national level. The study provides valuable insights into the management of limited data sets and the assessment of their alignment with officially defined indicators. Therefore, its applicability extends beyond geographical boundaries, providing a relevant resource for international researchers facing similar challenges.

The proposed framework, however, has some limitations. First, some of the data sources were not provided at the scale of single municipalities and were impossible to downscale. Furthermore, significant differences in the number of residents across municipalities resulted in computed rates that, despite being accurate, could not be fully representative (thereby exemplifying the modifiable areal unit problem[56]). As a consequence, equal weighting, sensible to extreme values, may have further biased the results. Finally, differences in the availability of data over time made it impossible to analyse the temporal trend in the SDG3 index, which represents an essential aspect. Also, possible indirect effects due to the COVID-19 pandemic could have impacted some indicators, potentially biasing the results.

Consequently, the following challenges should be addressed in further research:

(1) Hierarchisation of SDGs indicators and targets: The UN does not provide guidelines for weighting, possibly implying either that all targets and indicators hold equal significance or that assigning specific weights universally across all UN member states proves unfeasible. In the latter scenario, future research could focus on assessing weights tailored to specific groups of countries, such as Mediterranean nations or European Union members, in particular by combining qualitative and quantitative methods (e.g., Delphi interviews, multiple-criteria decision analysis, dimensionality reduction, and regression analysis). Additionally, to this purpose, detailed sensitivity and statistical robustness analyses should be provided as their absence constitutes a limitation of the presented approach.
(2) Spatial monitoring of SDG3 achievement at local levels: Once detailed geographical granularity of the data is ensured, deeper quantitative and qualitative analyses to unravel the underlying drivers of spatial disparities will be crucial. Techniques such as spatial econometrics, geographically weighted regression, and spatial autocorrelation analysis could help identify and quantify the spatial patterns and the influence due to various health-related indicators. Furthermore, using mixed-effects models could allow for the assessment of both fixed and random effects across different spatial units, thus providing a better understanding of local variations.
(3) Temporal monitoring of SDG3 achievement at local levels: In addition to the importance of longitudinal analyses to follow municipal improvements over time, the current findings underscored the significant scarcity of available data, as well as their unavailability over time. However, this study can serve as a catalyst for initiating a systematic temporal assessment of annual progress at the municipality level for Italy. By establishing a robust framework for ongoing monitoring, future research could contribute to a deeper understanding of health trends within communities, thereby informing more targeted policy interventions and resource allocation strategies.
(4) Call for policymaking: Even with partial data, relevant quantitative studies provide insights sufficient for tailoring new local policies. Based on statistical results, future qualitative research can formulate localised policy interventions that can contribute to achieving the broader objectives of Agenda 2030 at the national level.

Author statements

Ethical approval

No ethical approval was required.

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Competing interests

The authors declare no conflict of interests.

Author contributions

Conceptualisation: J. N., L. G. and E. G. C. Data curation: J. N. Formal analysis: J. N. Investigation: J. N. Methodology: J. N., L. G. and E. G. C. Project administration: E. G C. Software: J. N. Supervision: E. G. C. Validation: J. N. and L. G. Visualisation: J. N. Writing—original draft: J. N. and L. G. Writing—review and editing: J. N., L. G. and E. G. C.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2024.08.014.

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