

Leveraging census data to design and implement an area-based deprivation index to assess health inequalities in Ecuador

Diego Andrade Ortiz^{1,2*}, Ruth Dundas¹, Jonathan R Olsen^{1,3}, Irina Chis Ster⁴, and on behalf of the SEDHI project⁵

Submission History

Submitted:	23/01/2025
Accepted:	30/09/2025
Published:	26/01/2026

¹School of Health and Wellbeing, University of Glasgow, Clarice Pears Building, 90 Byres Road, Glasgow, G12 8TB, UK

²Maestría de Investigación en Ciencias de la Salud, Universidad Internacional del Ecuador, Av. Simón Bolívar y Av. Jorge Fernández, Quito, Ecuador

³Institute for Social Science Research, The University of Queensland, Brisbane QLD 4072, Queensland, Australia

⁴Institute of Infection and Immunity, City St. George's University of London, Office: 2.028A, Jenner Wing, Cranmer Terrace, London, SW17 0RE, UK

⁵NIHR Global Health Research Unit on Social and Environmental Determinants of Health Inequalities

Abstract

Introduction

Deprivation measures have been used in research to assess within-country health inequalities globally. Most of these indices are created using data from national census, given their availability and nationwide coverage.

Objectives

This study aims to create a census-based deprivation index in Ecuador, the Ecuadorian Deprivation Index (EDI), that reflects the country specific context using national census data for four geographical units (census sector, parish, canton and province). It will be compared to two traditional small area indices (Townsend and Carstairs) to assess the most appropriate and context specific index for Ecuador. Finally, the performance of the three indices will be assessed by examining the association and extent of inequalities with teenage pregnancy as this has been shown to be socially patterned in other countries.

Methods

This study uses the 2010 Ecuadorian census and follows the stages and recommendations for developing small-area deprivation indices. The Townsend and Carstairs are firstly replicated. For the EDI, Principal Component Analysis is used to select the most appropriate indicators. Summary measures for higher-level geographical areas were developed following the techniques used in the English Index of Multiple Deprivation. Inequalities in teenage pregnancy is measured using the Slope index of inequality and the Relative index of inequality.

Results

The three indices exhibit a good match in urban areas and can describe pattern of inequalities in teenage pregnancy. However, the EDI Index captures rural deprivation more appropriately and that includes the Coast and Amazon geographical regions.

Conclusions

Traditional deprivation measures may not adequately identify deprivation in Ecuador, given the country's unique specific contextual factors. The wider scope of the EDI will inform policy-makers towards developing tailored programs to alleviate deprivation and health inequalities in Ecuador.

Keywords

deprivation; deprivation index; principal component analysis (PCA); health inequalities; urban; rural; Ecuador

*Corresponding Author:

Email Address: diandradeor@uide.edu.ec (Diego Andrade Ortiz)

Introduction

Deprivation indices have been widely used to explain differences in health patterns and inequalities within various populations, especially in the Global North, since the late 1970s [1–3]. The deprivation indices are well utilised for health research purposes and continue to be developed in new contexts [1–3]. In a recent study conducted by Zelenina et al. (2022), sixty deprivation indices used in public health from seventeen countries were identified in geographic areas of North America, Europe, Australia, and New Zealand, with at least 16 created in the last 10 years. Several more are available for other regions [4–7], and the number is growing. These 'indices' are based on a combination of variables hypothesised to describe deprivation, defined as lack of accessible resources and opportunities. The first deprivation indices were developed in the UK by Townsend [8], Carstairs [9] and Jarman [10].

Deprivation measures can be extended to include material and social dimensions that can be understood to be determinants of health, and, in turn, help explain patterns of inequalities in the health of a population. The World Health Organisation (WHO) considers the determinants of health to be material circumstances, psychosocial circumstances, behavioural and biological factors, and the health system itself [11, 12]. Deprivation measures, such as indices, help in the research of how material determinants of health shape health outcomes.

The most widely used source of data for the development of deprivation indices is census data [13]. Census data collect updated information on the population of a country including demographics, socioeconomic status, level of education, housing conditions, ethnic composition, and employment, among others. As such, deprivation measures can be used to highlight local health disparities. Another growing source of information for the development of deprivation indices is administrative data that are produced by governmental agencies. These datasets bring information from different sectors with the benefit of being regularly updated. Although the statistical production of administrative data has been improved in recent years in Ecuador, a vast majority of these data are not available for small area level (i.e., census sectors or even parishes and cantons) and with different periods of publication and quality. Currently in Ecuador and other low and middle income settings, census data is the most appropriate source to use. Census uses the same statistical design and collects information from different domains/dimensions at the same point in time from the same research units (individuals and dwellings).

Health research in Ecuador is faced with two main limitations. Firstly, socioeconomic indicators (i.e., poverty measures) are not available at the level of disaggregation needed to perform ecological analysis in municipalities or smaller administrative areas (e.g., parishes). Secondly, health outcomes are available at aggregate levels (i.e., provinces, municipalities, and parishes) and not at individual levels, limiting the possibilities of data linking and using other techniques that require individual data. Therefore, it is necessary to develop socioeconomic measures of deprivation at the level at which health outcomes are published.

There are a number of previous deprivation indices developed for Ecuador using the 2010 Census. Peralta et

al. [14] used census and survey data at the municipal level (canton), which are highly heterogeneous in terms of population size. Cabrera-Barona et al. created two indices at the small area level, but only for the city of Quito and one of its parishes [15, 16]. Obaco et al. used data from surveys (2010–2017) to create a deprivation index at province level [17]. However, to date, this study proposes one of the first deprivation indices constructed using whole-population Census data and the smallest possible geographical structure, namely census tract. The advantage of such approach is that aggregation can be performed at various geographic levels, namely, to match those of health outcomes.

This study uses the conceptual/theoretical framework of material deprivation, initially proposed by Townsend [18] and later operationalised in the development of indices with indicators related to this concept. We replicated the Townsend and Carstairs indices and propose a new index for the Ecuadorian case, with the objective of comparison and evaluation. Townsend considered deprivation as a condition of lacking opportunities not only related to income (as measures of income poverty), but related to social, environmental, and other factors. These conditions may well vary in every society and are mostly related to diet, clothing, housing, education, work, and the environment. Deprivation can be understood as a condition that falls below the living standard of a particular society. Townsend's contribution reflects the idea of contextualising poverty as relative deprivation beyond just money income [8].

This conceptualisation of deprivation as a relative measure for each society has been used to develop area-based measures of deprivation for categorising the socioeconomic status of an entire neighbourhood, communities, or bigger areas. On the other hand, the concept of poverty aims primarily at characterising the socioeconomic status of individuals and/or families. This concept has also evolved to include indicators beyond income-based measures such as access to social services, educational attainment, health status and others [19, 20].

Deprivation measures based on Carstairs and Townsend indices have been replicated outside the U.K. in order to study health related outcomes in other settings such as the U.S. [21–23], Oceania [24], Europe [25, 26], Asia [27], but we could not find previous studies in South America. These indices have also been used as benchmarks to compare the performance and to validate newly developed indices [28–30].

The aim of this paper was to develop a new deprivation index for Ecuador, compare it to two traditional indices, and test its validity against a health outcome. Furthermore, the broad scope index is based on the concept of multiple deprivation [31]. First, Townsend- and Carstairs-style indices are recreated using the variables and methods initially proposed but adapted to data availability and recommendations from the literature. In particular, car ownership, which was an original indicator for Carstairs and Townsend indices, was replaced by an education indicator. Second, a new deprivation measure is proposed using other census variables and using principal component analysis (PCA) for its selection and can be summarised at different geographic or administrative levels. Since Townsend's original concept states that deprivation is relative to each society, we proposed a new index with a set of indicators that have been identified

for the Ecuadorian case. Finally, the three indices are validated against one health outcome (teenage pregnancy) available from the same census data at census sector, while the index summary at municipality level is compared with a previous published index.

Methods

Allik et al. [32], proposed a methodological framework for creating small area deprivation measures consisting of five stages: '1. Selection of appropriate data and geographic area. 2. Selection of individual deprivation indicators. 3. Constructing the index: combining and weighting indicators. 4. Validation and sensitivity analysis. 5. Dealing with uncertainty'. This framework was subsequently used to develop a small area deprivation index for Brazil (IBP – Brazilian Deprivation Index) [33]. It is important to note that this process is not linear and that re-assessments are performed based on validation. These stages follow the same basic structure as that followed by other authors in previous research [34–36]. The present study uses this methodological framework in the development and comparison of three indices for the Ecuadorian case using census data from small areas. Figure 1 presents the flow chart of the processes followed in the creation of the indices according to the stages discussed above.

Selection of appropriate data and geographic area

Ecuador is a middle-income country with a current per capita GNP of US\$ 6.400 [37] located in the northwest of South America. With a total population of 16.9 million inhabitants recorded in the 2022 census [38], it is the second-smallest country in the Andean region. The country is divided into four natural regions (Sierra, Coast, Amazon, and Galapagos), 24 provinces, and 221 municipalities. Ecuador is mainly populated (72%) by Mestizos (mixed ethnic groups), followed by some minority groups: Afro-Ecuadorian/black (7%), Montuvio (7%), Indigenous (7%) and White (4%) [39].

The 2010 census was chosen since it was last available at the time this project started. The census collected information on 72 questions throughout the country in four main sections: housing conditions, household characteristics, migration, and population. The later section covered topics related to demographics, education, employment, social security, fertility, and mortality. The data are summarized in Table 1.

A total of 40.628 census sectors were included in the analysis at the national level, with a mean population size of 354 inhabitants (SD of 164.9) (Figure 2). Exclusion criteria were applied to the data set to include only houses with people present and people with habitual residence within the country and excluded 12 census sectors without individual and household information. In total, approximately 0.74% (103,369 inhabitants) of the total population registered in the original published census database were excluded.

Selection of census variable indicators

Townsend, Carstairs, and a broader scope index using census data (the Ecuadorian Deprivation Index, or EDI) were

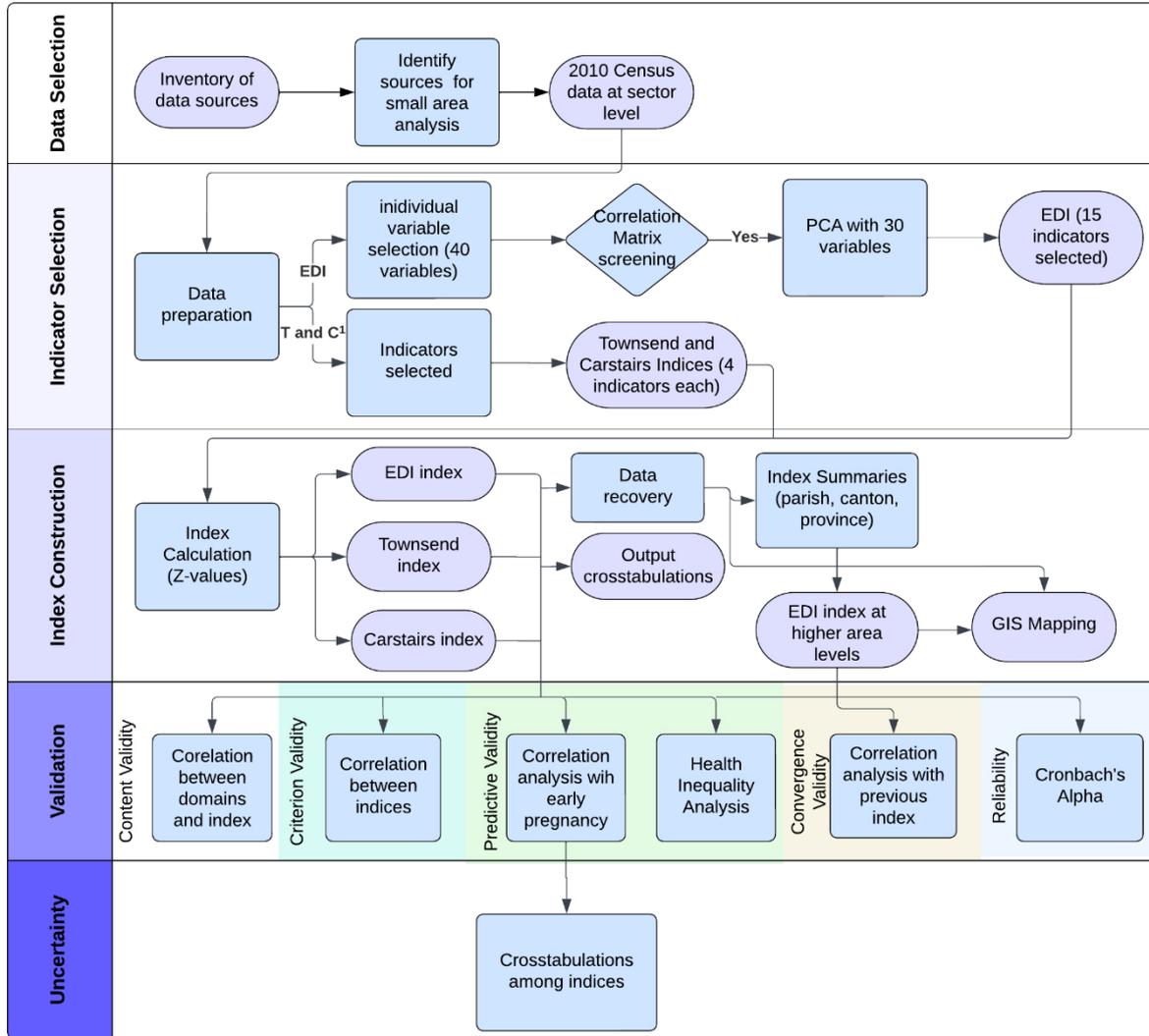
calculated using the Ecuadorian 2010 Census and the census sector as a geographic area. All variables were aggregated from individual data at the census sector level and transformed into percentages.

For the selection of the deprivation indicators, overcrowding and unemployment (original variables) were kept for the Townsend and Carstairs indices, while 'not owned housing' and a proxy of 'low social class' were used as originally proposed by Townsend and Carstairs, respectively. A variable 'no car ownership' was replaced by the no qualifications/education indicator, as proposed by Allik et al. [40] in the revised version of the Carstairs index for Scotland. The use of car ownership to measure deprivation has been criticised for not accurately representing the need for cars (instead of measuring wealth) in rural areas. Since this variable was not available from the census and is not social expectation in Ecuador, it was replaced by a variable related to education.

For the broader scope index (EDI index), a principal component analysis was performed on a total of 30 previously selected variables (40 variables selected from first screening and 10 discarded in the second screening) from the census questionnaire that were related to previous developments of deprivation indices. In particular, the scoping review by Zelenina et al. [13] (Table S2), who collected the indicators used in the development of 60 previous deprivation measures and the scoping review by Ichihara et al. [7] who described area deprivation measures used in Brazil were used as references to select the indicators for this study. Furthermore, the indicators used in previous studies related to Ecuador [14, 16, 17] (see Appendix 1) were also used as critical references to identify the indicators for this study. The first screening reviewed all variables of the census questionnaire (148 in total) and selected 40 that were related to the Townsend deprivation framework. In the second screening, 10 variables that were redundant because they showed the same phenomenon (i.e., the percentage of houses with damaged roofs and the percentage of houses with roofs in bad condition) were discarded. A number of 25 additional variables to the 5 used in the construction of the Townsend and Carstairs indices were identified, depicting education, socioeconomic characteristics, housing, and living conditions. The description of the indicators used in the principal component analysis (PCA) is presented in Supplementary Appendix 2. Principal component analysis was used to reduce the number of variables from these 30 to those variables that are highly correlated with the latent construct of deprivation. PCA can be used as a data reduction technique by identifying the principal components as linear combinations of the input variables that maximise the total variance [41, 42]. Therefore, PCA identified the variables that explain the highest proportion of the variability in the data and therefore those variables that have the highest correlation with the underlying deprivation construct are retained and those that are not are excluded.

A statistical test was performed to assess the suitability of the data before applying PCA. The overall Kaiser-Meyer-Olkin sampling adequacy measure (KMO test) was 0.95, showing that the correlation patterns are compact (values close to 1). The KMO values for each of the 30 items (indicators) were found to be greater than 0.50. The Bartlett sphericity test is significant: $\chi^2(435) = 915061$, ($p < .001$) supporting

Figure 1: Flowchart of the methodology used in the EDI development



¹T = Townsend, C = Carstairs.

Table 1: Population size, number, and type of census sectors by region included in the study

	Mean Pop	SD Pop	Total Pop	Pop (%)	N = Sectors	N (%)
Region						
Sierra	312.24	154.21	6,041,520	42.0%	19,349	47.6%
Coast	407.13	161.10	7,559,967	52.6%	18,569	45.7%
Amazon	284.41	155.62	723,243	5.0%	2,543	6.3%
Galapagos	329.20	159.37	23,044	0.2%	70	0.2%
Not Delimited ^a	333.57	133.64	32,356	0.2%	97	0.2%
Total	353.95	164.97	14,380,130	100.0%	40,628	100.0%
Urban Rural^b						
Urban	438.58	142.59	9,019,001	62.7%	20,564	50.6%
Rural	267.20	139.29	5,361,129	37.3%	20,064	49.4%
Total	353.95	164.97	14,380,130	100.0%	40,628	100.0%

^aNot Delimited areas by the time of the census. These areas were included in all forthcoming calculations but will not be presented in the output tables.

^bGovernmental administrative assignment of areas where only head of cantons are urban; otherwise, they are considered rural. Pop: Population.

a correlation matrix statistically different from an identity matrix and a component analysis approach for investigating the data.

PCA was applied to the 30 previously selected variables to identify the variables that would be correlated with the first component. The results of this exploratory technique are

Figure 2: Histogram of census sector population size

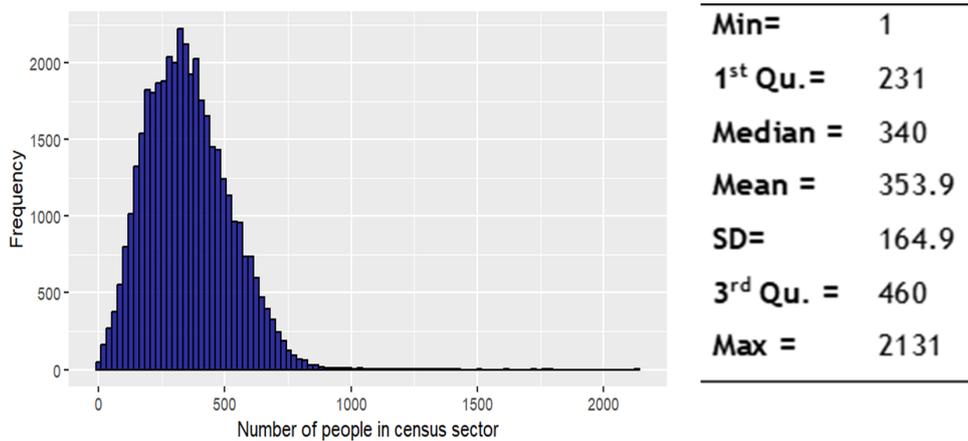
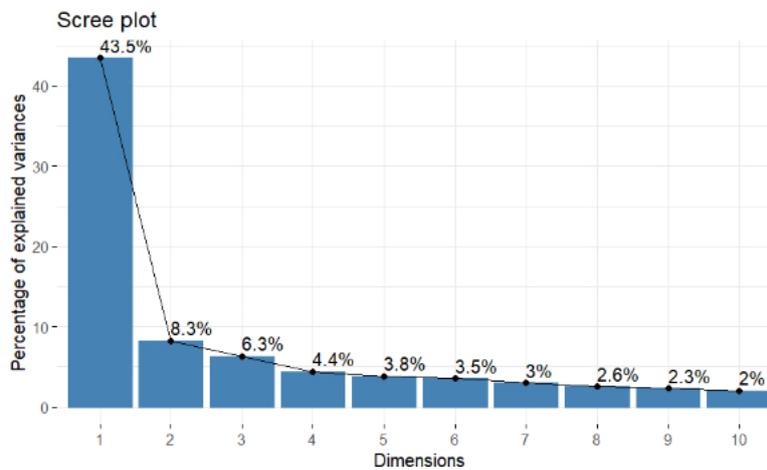


Figure 3: Scree Plot of the Principal Component Analysis



¹Dimension 1 = Component 1.

presented in Figure 3, the scree plot identified a principal component, which explained 43.5% of the variance, the next component accounts only with 8.3% of the variance and the third 6.3% showing that the first component captures most of the information before the scree line considerably changes its angle. On the auxiliary PCA with only the selected fifteen variables the first component accounts for the 68% of the variability in the data. The variables for the EDI were selected based on the analysis of the correlation matrix and the results of the PCA analysis. Thirteen variables were selected from those that had loads greater than 0.7, common variance greater than 0.5 and contribution greater than average ($1/30 = 3.3\%$). Additionally, two variables (low employment categories and overcrowding) were selected, given their proximity to previous cutoff points and their theoretical importance to the concept of deprivation. In total 15 indicators from 5 domains (see Table 2 for the descriptors of the variables used in the construction of Townsend, Carstairs, and EDI deprivation measures) were selected for the construction of the Ecuadorian deprivation index.

Figure 4 presents a biplot of the census sectors stratified by urban-rural classification (as used in Ecuadorian official statistics) and the indicators selected by the PCA. It can be observed that the 15 selected variables represent the latent

concept of deprivation on the horizontal axis of the plot, and the rural sectors (green) are found to be plotted mostly on the right-hand side, meaning higher deprivation levels than urban census sectors for the same 15 indicators.

Index construction

The variables were standardised, and the resulting Z-values were added together to obtain the measures for each index. This method of adding the resulting Z-values was followed by Townsend and Carstairs, meaning that each variable contributes an equal weight to the index.

The means of the standardised indicators for each of the five domains were calculated and added with equal weights to obtain the Ecuadorian deprivation index. Each domain was assigned the same weights, assuming that each is equally important to measure deprivation. Without previous evidence of the weights of the five identified domains the equal weight approach was chosen. To compare the resulting indices, they were classified in population-weighted quantiles (quintiles and deciles) and crosstabulations with the most important axis of inequality (area, sex, ethnicity, and age groups, urban-rural classification and geographical regions) were performed.

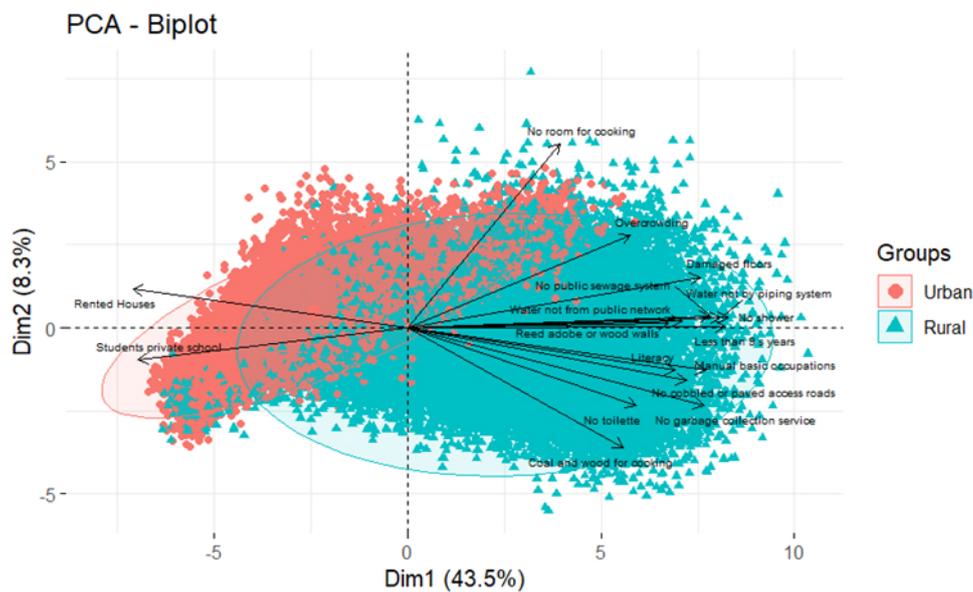
Table 2: Descriptors of deprivation indicators used by domain

Domain	No	Indicator	Dep. Indices ^a			Mean	SD	Median ^b
			C	T	E			
Education	1	% people less than 9 schooling years	•	•	•	61.8	19.8	63.38
	2	% of literacy			•	9.41	7.51	7.27
Employment	3	% of people in manual basic occupations			•	45.3	27	37.31
	4	% of unemployed out of active people	•	•		4.78	4.77	4
Housing	5	% of houses with reed, adobe or wood walls			•	26.3	28.6	14.39
	6	% of houses rented		•	•	18	18.1	12.28
	7	% of houses with damaged floors			•	56.8	24	59.13
	8	% of houses that receive water not by piping system			•	46.9	35	40
	9	% homes with more than 3 ppr	•	•	•	15.8	10.2	14.51
	10	% of houses with no shower			•	39.8	32.8	32.91
Socio-Economic Position	11	% of students in private establishments			•	23.3	20.3	18.37
	12	% of workers in low occupation categories	•		•	22.1	20.4	14.89
Living environment	13	% of houses without public sewage system			•	54.8	43.4	64.29
	14	% of houses without garbage collection service			•	33.7	40.8	8.22
	15	% of houses without cobbled or paved access roads			•	43.4	36.4	37.8
	16	% of houses with water supply not from public network			•	35.6	40.4	11.9

^aDeprivation Indices: C = Carstairs index, T = Townsend index, E = EDI index.

^bAll variables expressed as percentages; the minimum value is 0 and the maximum is 100.

Figure 4: Results from the Principal Component Analysis



To summarise the index into higher geographical areas corresponding to the political and administrative division of Ecuador, two methods used in the IMD for England case were adopted [43]. Both the population weighted average score, and rank are calculated for parishes, cantons, and provinces. The former has the characteristic of not average out in high-deprived areas to the same degree as when using ranks.

To have information for all 40,628 census sectors (completeness), a data recovery procedure was established

before summarising the index at higher levels (EDI index) and for mapping all census sectors in the GIS system (all three indices). Missing information for each indicator was imputed by averaging the nearest higher hierarchical area. Only 37 (.1%), 37 (.1%) and, 73 (.2%) census sectors were subject to this procedure for Townsend, Carstairs and EDI indices, respectively. Sensitivity analysis showed an ignorable effect of the imputation on index descriptors. EDI visualisation has been conducted using ArcGIS Pro 3.2.2 a Geographic Information System (GIS) software.

Index validation

The validation of the proposed index was carried out using the three criteria proposed by Pampalon et al. [44] and Carr-Hill et al. [34]: validity, reliability, and responsiveness. *Validity* is tested using the following three approaches: content validity, criterion validity, and construct validity. *Content validity* refers to the agreement between the broad concept of deprivation and its indicators and dimensions. Content validity will be tested using Spearman's correlations between the obtained index and its dimensions. A high level of correlation between the index and the identified dimensions is expected. The second approach, *criterion validity* understood as the ability of an index to correlate highly with other measures of deprivation, will be tested by comparing the three indices using correlation analysis.

The third approach, *construct validity*, investigates how consistent the relationships are between the deprivation measure and other health or social outcomes. Pampalon et al. [44] propose that this validity approach could be better understood in terms of convergence and predictive validity. *Predictive validity* refers to testing the performance of the deprivation index in explaining associations with health outcomes. These can be chosen from the mortality and morbidity outcomes and used to test a specific deprivation index. *Convergence validity* refers to comparing the index with external measures that reflect deprivation not only with measures from census data.

Reliability or internal consistency refers to the ability of a certain index to produce the same result under the same circumstances and is usually tested by analysing the degree of correlation between the indicators that make up the index using Cronbach's Alpha. Finally, *responsiveness* is related to the ability of a deprivation index to detect differences or changes depending on time, location, and individual characteristics.

To test predictive validity, a health outcome was chosen from the same census data at the sector level, and both correlation and health inequality analysis were carried out. Teenage pregnancy, for this analysis, is defined as the percentage of females experiencing first pregnancy between 12-18 years of age. The univariate statistics of this health outcome are presented in Table 3, the national average percentage of teenage pregnancy reaches 23.81%, with higher percentages found in the Amazon region (33.29%), the Coast (28.41%) and the rural area (26,21%). The Spearman

and Pearson correlations between the indices and teenage pregnancy are calculated. The gradient of inequalities is shown by tabulations between the rates of teenage pregnancy and the quintiles of deprivation of each index. Furthermore, the absolute gap or difference (D), the relative gap or ratio (R), the Slope index of inequality (SII) and the Relative index of inequality (RII) are calculated to assess and compare the performance of the deprivation indices in identifying health inequalities [45].

Internal consistency was tested by calculating the Cronbach's Alpha for individual indicators that were selected after the PCA analysis for the EDI index. The convergence validity and responsiveness were tested using index summaries in higher geographical areas, the ranks of the proposed index were compared with a previously published deprivation index for Ecuador. Peralta et al. [14] developed a deprivation index at the municipal level (canton) using information from the 2010 census and the 2013-2014 national Living Conditions Survey. Both, Spearman and Kendall's Tau-b rank correlations were calculated.

Dealing with uncertainty

The final step in creating deprivation indices is dealing with uncertainty. Every measure of deprivation is an estimate of a 'true' value that cannot be observed directly. Therefore, a common way researchers face this issue is by using categorical measures of deprivation (i.e., quintiles or deciles) obtained from the continuous index measure. Transforming the index scores into categorical measures reduce uncertainty by splitting the areas into groups; hence, small variations in the score generally have no impact on the assigned quantile [32]. Another way to deal with uncertainty is by calculating cross-tabulations among available indices or measures of deprivation [32, 33, 46]. Most areas are expected to fall on the diagonal of the cross-tabulated table, showing that the uncertainty about the deprivation measure is small [40]. For this analysis, the three indices are cross-tabulated and compared using population-weighted deciles.

Results

Deprivation indices results

Table 4 presents the distribution characteristics of the three deprivation indices obtained in this study at census sector level.

Table 3: Descriptors of teenage pregnancy in Ecuador by region and urban and rural areas

	Mean	SD	Min	Median	Max
Region					
Sierra	18.11	8.52	0.00	17.28	100.00
Coast	28.41	11.43	0.00	28.36	100.00
Amazon	33.29	12.73	0.00	32.63	100.00
Galapagos	22.05	7.86	8.33	22.07	50.00
Urban Rural					
Urban	21.48	10.10	0.00	20.51	100.00
Rural	26.21	12.61	0.00	25.00	100.00
Total	23.81	11.65	0.00	22.43	100.00

Table 4: Deprivation indices descriptors

	N ¹	Mean	SD	Median	Min	Max	Range	Skew	Kurtosis
Townsend Index	40591	0.00	2.56	0.25	-10.19	22.70	32.89	0.18	1.13
Carstairs Index	40591	0.00	2.49	-0.07	-6.75	24.55	31.30	0.50	1.59
EDI Index	40555	-0.01	4.55	-0.22	-9.11	11.38	20.49	0.08	-1.14

¹Number of census sectors.

Table 5: Percentage of the population in Q4 and Q5 (highest deprivation quintiles) by deprivation index

	Townsend index	Carstairs index	EDI index
Region			
Sierra	9.5%	9.4%	13.1%
Coast	27.9%	28.2%	23.6%
Amazon	2.4%	2.3%	3.1%
Galapagos	0.0006%	0.0004%	0.0116%
Urban Rural			
Urban	17.2%	17.1%	10.0%
Rural	22.8%	22.9%	30.0%

The histograms of the three indices, segmented by urban or rural areas, are presented in the Supplementary Appendix 3. The bimodal distribution of the EDI index is explained by the left component being described by urban deprivation and the right component (higher) by rural deprivation. Carstairs and Townsend indices do not differentiate between urban and rural distributions.

The results obtained from the cross tabulation between quintiles (population weighted) by population count and by region and urban-rural areas are presented in the Supplementary Appendix 4 (Q1 = Less deprived to Q5 = Most deprived) (Table 5).

Analysing cross-tabulations of the deprivation quintiles by axis of inequalities, the three indices presented similar results in sex and age, but sensible differences by ethnic auto-identification. In the case of sex, no differences or inequalities were found by either index at the aggregate level. In the case of age groups, the Townsend, Carstairs, and EDI indices presented similar results, with a similar proportion (46%) of young (0-14 years) in Q4 and Q5. The proposed index has a slightly higher proportion of people 65 years or older in Q4 and Q5 (Supplementary Appendix 5). In the case of ethnic auto-identification, the Mestizo and Montuvio groups have similar distributions in the quintiles of the three indices, while the Indigenous and Afro-ecuadorian groups present the highest differences. The Ecuadorian Deprivation Index categorises a higher proportion of indigenous people in the two highest quintiles and a lower proportion of Afro-Ecuadorians relative to Townsend and Carstairs (Supplementary Appendix 6).

The results of summarising the EDI index, as population weighted averages of index scores, to the administrative-political division of the country are presented in the supplementary appendices, parish (Supplementary Appendix 7), canton (Supplementary Appendix 8), and province (Supplementary Appendix 9).

The geographic maps of the deprivation indices presented in Figure 6 show the EDI index presents a higher proportion of census sectors on the darker colour scale, depicting higher deprivation in rural areas. Both the Townsend and Carstairs indices represent lower deprivation even in geographical areas with low population density and at considerable distances from towns and villages, such as in the eastern part of the Amazon Region, the central part of the Coast, and the southern part of the Sierra Region. A closer analysis of the maps shows how the main urban areas of the country have lower levels of deprivation and are surrounded by 'deprived areas'. In this case, the three indices present similar results.

Validation of the deprivation index

Content validity was tested by the Spearman correlations between each of the five domains and the proposed measure

Figure 5: Spearman correlations between EDI and deprivation domains

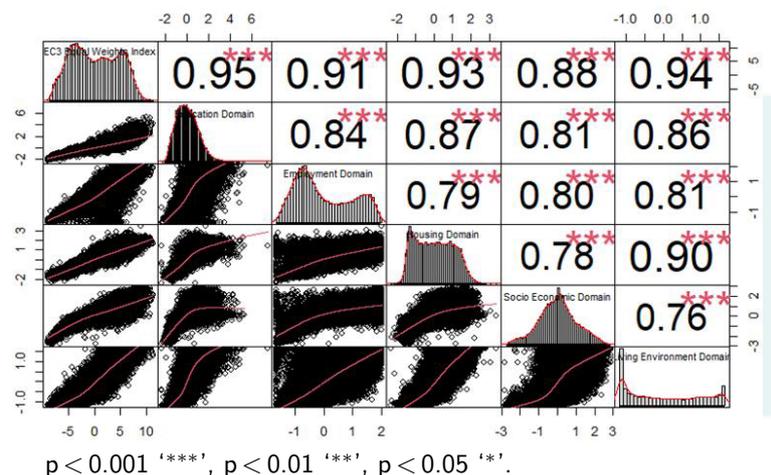
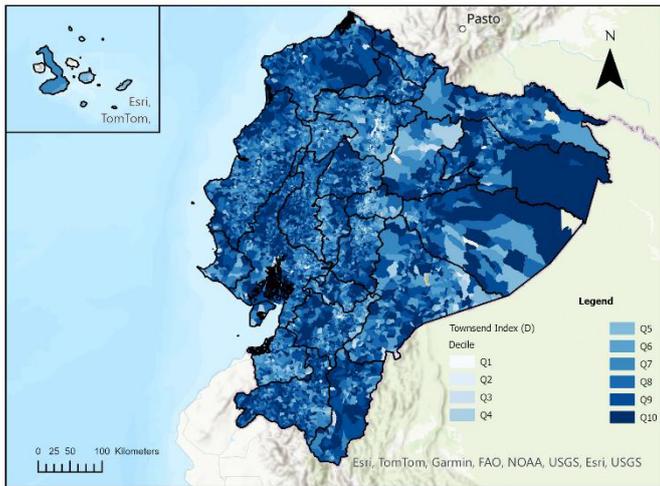
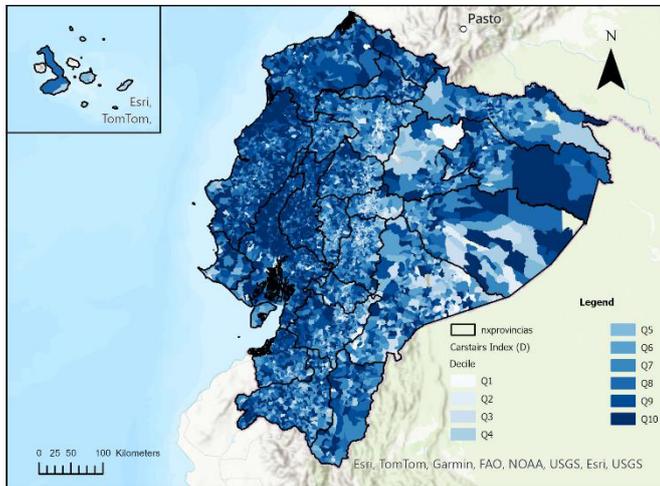


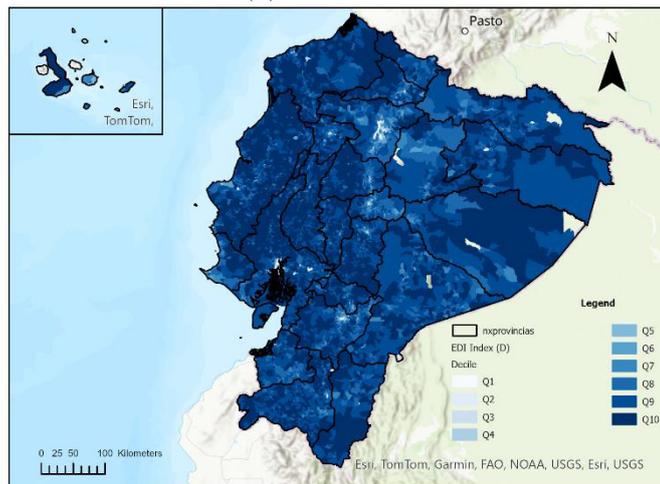
Figure 6: Deprivation Indices Maps by deciles for each of the deprivation indices



(a) Townsend Index



(b) Carstairs Index



(c) EDI Index

of deprivation (EDI index) (Figure 5). The domains of education and living environment had the highest correlation with 0.95 and 0.94, respectively, followed by the housing domain (0.93), employment (0.95) and the socioeconomic domain (0.88). It is important to note the high inter-domain

correlation, as expected, and to explain the latent construct of deprivation.

Criterion validity was tested by comparing the correlation coefficients between the three indices (Table 6). Pearson's correlation coefficients measure the linear correlation between the scores of the indices, while Spearman's coefficients measure the correlation between the ranks of the indices. The Townsend and Carstairs indices had a very strong correlation (Pearson=0.918, Spearman=0.92), while the EDI index had a lower but still strong correlation with both the Townsend (Pearson=0.793, Spearman=0.816) and Carstairs indices (Pearson=0.787, Spearman=0.809). Despite the differences in their construction, these results show the common agreement about the underlying concept of deprivation between the indices.

Predictive validity was conducted using one health outcome available from the same census at the same area level. Table 6 presents the correlation matrix (Pearson and Spearman coefficients) between teenage pregnancy and the three deprivation indices. Teenage pregnancy presented Spearman correlations between 0.533 (EDI index) and 0.657 (Carstairs index). Teenage pregnancy is positively correlated with the three indices, which means that the percentage of women older than 12 years with their first pregnancy before 18 years is higher in the highest quintiles of deprivation (Figure 7).

Measures of inequality are presented in Table 7 for all the three indices and shows how the average teenage pregnancy percentages increase with deprivation (higher quintiles). The Carstairs index shows the highest absolute difference (D) and the highest ratio (R) between the most deprived quintile (Q5) and the least deprived quintile (Q1) with 21.72 percentage points and a ratio of 2.5. The EDI index presents the lowest absolute difference (18.37) and the second highest ratio (2.51) but very close to that of Townsend's (2.50). The SII and the RII of all three indices show higher levels of inequality for the most deprived quintiles. Carstairs and Townsend index present a SII of 24.4 (21.57-27.23) and 26.74 (24.22-29.25) respectively. The EDI index presents the lower slope with 23.44 (15.6-31.28) and the lower relative index 3.03 (1.91-4.79).

The measure of internal consistency of Cronbach's alpha applied to the 15 selected variables reached a value of $\alpha = 0.94$, showing that the deprivation index subscale is reliable. Convergence validity and responsiveness of the proposed index were tested using a comparative analysis between the ranks of the proposed index (EDI) and the deprivation index developed by Peralta et al. [14] at the municipal level (canton) are presented in Table 8. Spearman's correlations for the three regions published in the previous study showed strong positive monotonic correlations (above 0.90) between the indices. Furthermore, the Kendall tau-b correlation showed a high positive association in terms of the agreement of orders between the two indices (above 0.82).

Dealing with uncertainty

The final step was to deal with uncertainty using cross-tabulations of population-weighted deciles for the different indices. Between the EDI and Carstairs and Townsend indices, the overall cross-tabulation (Supplementary Appendix 10)

Table 6: Correlations between teenage pregnancy and deprivation indices

Pearson \ Spearman	Teenage pregnancy	Townsend index	Carstairs index	EDI index
Teenage pregnancy	1	0.576***	0.657***	0.533***
Townsend index	0.546***	1	0.920***	0.816***
Carstairs index	0.612***	0.918***	1	0.809***
EDI index	0.525***	0.793***	0.787***	1

p < 0.001 '***', p < 0.01 '**', p < 0.05 '*'.

Figure 7: Association between 'teenage pregnancy' and deprivation indices

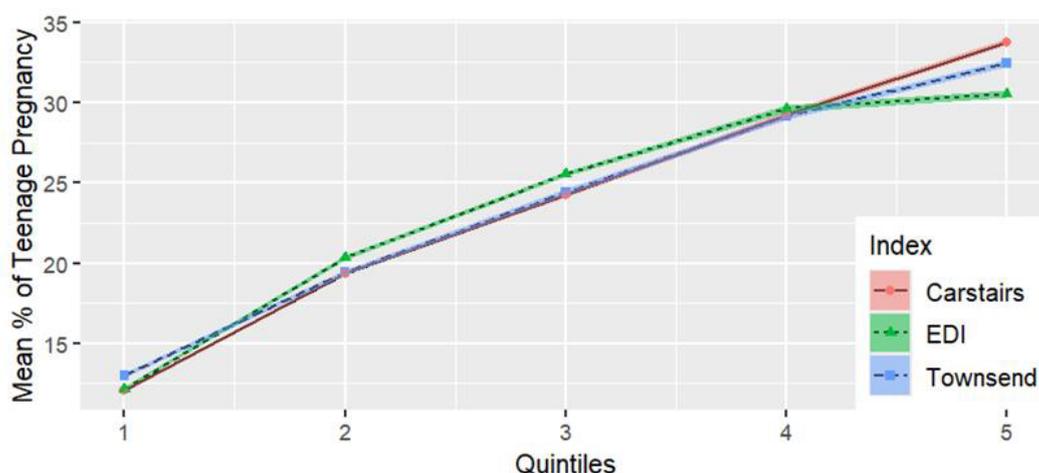


Table 7: Average teenage pregnancy percentages by Quintiles of deprivation and health inequality indicators

	Townsend Index ¹	Carstairs index ¹	EDI index ¹
Quintile (Weighted)			
Q1 = Less deprived	13 (12.87–13.14)	12.06 (11.94–12.18)	12.18 (12.06–12.3)
Q2	19.4 (19.25–19.55)	19.38 (19.25–19.52)	20.34 (20.2–20.47)
Q3	24.43 (24.25–24.6)	24.23 (24.07–24.4)	25.56 (25.38–25.74)
Q4	29.12 (28.92–29.32)	29.23 (29.04–29.43)	29.62 (29.4–29.84)
Q5 = Most deprived	32.45 (32.23–32.68)	33.78 (33.57–33.99)	30.55 (30.33–30.77)
Total	23.29 (23.19–23.4)	23.29 (23.19–23.4)	23.29 (23.19–23.4)
Health Inequality indicators			
Difference (D) - Absolute GAP	19.45 (19.19–19.71)	21.72 (21.48–21.97)	18.37 (18.12–18.62)
Ratio (R) - Relative GAP ²	2.5 (2.46–2.53)	2.8 (2.77–2.83)	2.51 (2.48–2.54)
Slope Index of Inequality (SII) ³	24.4 (21.57–27.23)	26.74 (24.22–29.25)	23.44 (15.6–31.28)
Relative Index Of inequality (RII) ³	3.2 (2.69–3.81)	3.69 (3.03–4.5)	3.03 (1.91–4.79)

¹Estimate (95% confidence intervals).

²Estimation using Fieler's method.

³Estimation using linear model.

does not yield a tight diagonal showing differences in the way each index classifies census sectors in deciles. However, the cross-tabulations only for urban areas (Supplementary Appendix 11) show the expected tight diagonal; this shows again that the main difference among the indices is the classification of the rural areas as identified before.

Discussion

Deprivation indices are useful measures in research to analyse associations between socioeconomic factors and important

health issues in the population [47–49]. Furthermore, previous research has indicated that 'the strength' of the association between deprivation measures and health outcomes depends on the size of the spatial unit used to create the index. There is evidence that the smaller the spatial unit used, the stronger the relationship with the health outcomes [44]. In the case of Ecuador, there have been some studies proposing deprivation measures with a number of limitations, here we developed and compared three small area-based country-wide measures of deprivation. The indices were developed following the guidelines, methods, and recommendations of previous guidance and research [31, 32].

Table 8: Correlations between EDI index and a Deprivation index developed by Peralta et al.

	Kendall's tau-b	95% Confidence Intervals (2-tailed) ^a		Spearman's rho	95% Confidence Intervals (2-tailed) ^{a,b}	
		Lower	Upper		Lower	Upper
Coast and Galapagos	0.825***	0.774	0.865	0.960***	0.938	0.974
Sierra	0.826***	0.777	0.865	0.953***	0.929	0.969
Amazon	0.856***	0.788	0.904	0.967***	0.938	0.983

$p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.

^a Estimation is based on Fisher's r-to-z transformation.

^b Estimation of standard error is based on the formula proposed by Fieller, Hartley, and Pearson.

This research analysed within the scope of Ecuador that two traditional measures of deprivation (Townsend and Carstairs Indices) could be useful in depicting urban deprivation, as they have been found in many other countries given the type of indicators used in their construction. But these indices may not seem relevant enough (long and thin right tails) for cases where rural areas have less access to services and a higher incidence of poverty than urban areas, failing to represent deprivation in higher geographical areas, such as regions. Other authors have reported similar findings in different settings, such as Cyprus [50].

We developed a wider scope index (EDI index) that includes variables from different domains and demonstrated it to be a better choice by including a higher number of census sectors and population in its construction. Although this might require understanding deprivation as a bimodal distribution where the components are explained by differences in the urban and rural continuum. The validation of the proposed index with an available health outcome (teenage pregnancy) showed its potential for conducting health inequality analysis in Ecuador.

The Townsend and Carstairs indices have a lower standard deviation (2.56 and 2.49, respectively) than the EDI index (4.55) but a much higher range. Histograms show that the EDI index has a bimodal distribution, while Carstairs and Townsend have a higher positive skewness. In terms of kurtosis, the EDI index has a flatter distribution (-1.14) than Carstairs (1.59) and Townsend indices (1.13). This is evident in the histograms of the indices (see Supplementary Appendix 3) where Townsend and Carstairs have a long and thin tail to the right (mainly attributable to census sectors located in rural areas).

The number of census sectors and the population count classified in quintiles are similar for the Carstairs and Townsend indices. Our EDI index has a higher proportion of sectors and population count classified in the most deprived quintiles (Q5) than the other indices. In terms of population and regions, the EDI index shows a higher percentage classified as Q4 and Q5 (6.4% and 6.7%) in the Sierra and on the Coast (Q4 = 12.6% and Q5 = 11%). In the case of the Amazon region, the EDI index also shows a higher proportion of people classified in higher quintiles (most deprived).

The analysis of deprivation in the rural-urban space remains a challenge given the contextual complexity of Ecuadorian administrative assessment [51–54]. Regardless of the complexity, it is important for countries like Ecuador to

have measures that can contrast socio economic differences between the urban and rural spaces. Considering the variability between urban and rural areas is one of the main strengths of this research, which includes a wide selection of variables that were considered important for classifying both urban and rural areas. This is important due to lower income mainly from agricultural activities, higher access barriers to quality education, and lower coverage of basic services in rural settlements. Using a PCA method [55–58] for dimension reduction, considering the theoretical framework, previous research and having present urban and rural distributions of deprivation for the analysis might be helpful in the development of deprivation measures in the Global South with a more balanced population proportion in the urban-rural space.

In the validation phase, the three indices performed as expected, with positive correlations with teenage pregnancy and similar results in the health inequality indicators (SII and RII) at the census sector level. Health inequality analysis clearly showed that average percentages of teenage pregnancies were higher for the most deprived areas. These results are consistent with previous studies that found similar results between deprivation and teenage pregnancy [61, 62]. Since the proposed EDI index captures inequalities better for rural and for the Sierra and Amazon regions, it is possible that greater differences could be found when health inequalities analysis with health outcomes is carried out in higher geographic areas. Using the summarise versions calculated for the index at the areas corresponding to the political and administrative division of the country could allow research of ecological studies with available health outcomes [63, 64]. Further analysis of the role of variables such as “rented houses” with opposite association with deprivation as expected, and the proxy use of socio-economic variables such as “Low occupation categories” and “students in private establishments” found in this research are also needed [12, 65, 66].

Although the methods and techniques were chosen according to previous experiences described in the literature, this study has some limitations. The census operations available for Ecuador lack information on income and poverty that could greatly improve the precision of the measures. Moreover this research is not immune to the well-known limitations of deprivation indices, such as the ‘ecological fallacy’ [52, 59, 60] and the low occurrence of some phenomena in small areas that limits the choice and availability of data. Even if this study contributes to the debate

about urban rural deprivation, the categorisation itself of this dichotomy must be addressed to overcome the 'legal' definition available in the Ecuadorian census with a more suitable 'urbanicity index' that accounts for other measures and gradients of rurality and urban spaces.

Conclusions

We have developed and validated a new deprivation index for Ecuador for research in health inequalities (EDI). The EDI has been developed at several small area units, shows improved performance than two traditional deprivation indexes we compared it to, and it accounts for urban-rural differences. The index was validated using different criteria proposed in the literature, mainly on its ability to capture an inequality gradient on a health outcome (teenage pregnancy) and was compared to a previous published index. Also, summarised versions of the index corresponding to the political-administrative areas of the country were calculated and could contribute to improving the understanding of the influence of deprivation on health at the ecological level.

Acknowledgements

The authors acknowledge the support of the SEDHI Project team (Unit on the Social and Environmental Determinants of Health Inequalities) for their participation, care and guidance. We would also like to thank all stakeholders of the project from Brazil and Ecuador for their invaluable insights and feedback.

Statement on conflicts of interest

The authors have no conflict of interest to declare.

Ethics statement

This study only used anonymised data published by the Ecuadorian Institute of Statistics and Censuses (INEC). No identifiable individual data was used in the study and therefore ethical approval was not required. However, this study received approval from the SEDHI Project Publications Committee.

Funding statement

This research was funded by the NIHR (NIHR134801) using UK international development funding from the UK Government to support global health research. The views expressed in this publication are those of the author(s) and not necessarily those of the NIHR or the UK government. JO and RD were supported by the Medical Research Council (MC_UU_12022/2; MC_UU_00022/4) and the Chief Scientist Office (Scotland) (SPHSU17; SPHSU19).

Data availability

Census data published by the Ecuadorian Institute of Statistics and Censuses (INEC) is available at <https://www.ecuadorenci>

frs.gob.ec/base-de-datos-censo-de-poblacion-y-vivienda-2010/. Supplementary data from the small-area index could be requested from the authors (corresponding author: Diego Andrade).

References

- Otavova M, Masquelier B, Faes C, Van den Borre L, Bouland C, De Clercq E, et al. Measuring small-area level deprivation in Belgium: The Belgian Index of Multiple Deprivation. *Spat Spatiotemporal Epidemiol* 2023 Jun.;45:100587. <https://doi.org/10.1016/j.sste.2023.100587>
- Pichardo CM, Ezeani A, Acevedo AM, Agurs-Collins T, Bailey-Whyte M, Dorsey TH, et al. West African Genetic Ancestry, Neighborhood Deprivation, and Prostate Cancer. *JAMA Network Open* 2024 Sep.;7:e2433546. <https://doi.org/10.1001/jamanetworkopen.2024.33546>
- Kumar RG, Delgado A, Corrigan JD, Eagye CB, Whiteneck GG, Juengst SB, et al. The TBI Model Systems Neighborhood Socioeconomic Disadvantage Index (TBIMS-NSDI): Development and Comparison to Individual Socioeconomic Characteristics. *The Journal of Head Trauma Rehabilitation*. <https://doi.org/10.1097/HTR.0000000000000968>
- Vasquez A, Cabieses B, Tunstall H. Where Are Socioeconomically Deprived Immigrants Located in Chile? A Spatial Analysis of Census Data Using an Index of Multiple Deprivation from the Last Three Decades (1992-2012). *PLOS ONE* 2016 Jan.;11:e0146047. <https://doi.org/10.1371/journal.pone.0146047>
- Wang K, Law C-K, Zhao J, Hui AY-K, Yip BH-K, Yeoh EK, et al. Measuring health-related social deprivation in small areas: development of an index and examination of its association with cancer mortality. *Int J Equity Health* 2021 Sep.;20:216. <https://doi.org/10.1186/s12939-021-01545-9>
- Noble M, Barnes H, Wright G, Roberts B. Small Area Indices of Multiple Deprivation in South Africa. *Soc Indic Res* 2010 Jan.;95:281–97. <https://doi.org/10.1007/s11205-009-9460-7>
- Ichihara MYT, Ramos D, Rebouças P, Oliveira FJ, Ferreira AJF, Teixeira C, et al. Area deprivation measures used in Brazil: a scoping review. *Revista de Saúde Pública* 2018 Aug.;52:83–83. <https://doi.org/10.11606/S1518-8787.2018052000933>
- Schervish PG. Peter Townsend. Poverty in the United Kingdom: A Survey of Household Resources and Standards of Living. Pp. 1216. Berkeley, CA: University of California Press, 1979. *The ANNALS of the American Academy of Political and Social Science* 1981 Jul.;456:182–3. <https://doi.org/10.1177/000271628145600134>

9. Carstairs V. Multiple deprivation and health state. *Journal of Public Health* 1981 Feb.;3:4–13. <https://doi.org/10.1093/oxfordjournals.pubmed.a043389>
10. Jarman B. Identification of underprivileged areas. *Br Med J (Clin Res Ed)* 1983 May;286:1705–9. <https://doi.org/10.1136/bmj.286.6379.1705>
11. WHO. A conceptual framework for action on the social determinants of health. WHO 2010;76.
12. Marmot M, Sharon Friel, Friel S, Ruth Bell, Bell R, Tanja A. J. Houweling, et al. Closing the gap in a generation: health equity through action on the social determinants of health. *The Lancet* 2008 Nov.;372:1661–9. [https://doi.org/10.1016/s0140-6736\(08\)61690-6](https://doi.org/10.1016/s0140-6736(08)61690-6)
13. Zelenina A, Shalnova S, Maksimov S, Drapkina O. Classification of Deprivation Indices That Applied to Detect Health Inequality: A Scoping Review. *Int J Environ Res Public Health* 2022 Aug.;19:10063. <https://doi.org/10.3390/ijerph191610063>
14. Peralta A, Espinel-Flores V, Gotsens M, Pérez G, Benach J, Marí-Dell'Olmo M. Developing a deprivation index to study geographical health inequalities in Ecuador. *Revista de saúde pública [Internet]* 2019;53. Available from: <https://go.exlibris.link/Gtppq2NQ>. <https://doi.org/10.11606/s1518-8787.2019053001410>
15. Cabrera Barona P, Blaschke T. Healthcare Accessibility and Socio-economic Deprivation: A Case Study in Quito, Ecuador. *GI Forum*. 2015;1:484–92. <https://doi.org/10.1553/giscience2015s484>
16. Cabrera-Barona P, Murphy T, Kienberger S, Blaschke T. A multi-criteria spatial deprivation index to support health inequality analyses. *International journal of health geographics* 2015;14:11–11. <https://doi.org/10.1186/s12942-015-0004-x>
17. Obaco M, Royuela V, Matano A. On the link between material deprivation and city size: Ecuador as a case study. *Land Use Policy* 2021 Dec.;111:104761. <https://doi.org/10.1016/j.landusepol.2020.104761>
18. Townsend P. Deprivation. *Journal of Social Policy* 1987 Apr.;16:125–46. <https://doi.org/10.1017/S0047279400020341>
19. Sen A. Capability and Well-Being [Internet]. In: Nussbaum M, Sen A, editors. *The Quality of Life*. Oxford University Press; 1993 [cited 2024 8]. p. 0. Available from: <https://doi.org/10.1093/0198287976.003.0003>.
20. Alkire S, Foster J. Counting and multidimensional poverty measurement [Internet]. Publisher's version. Oxford Poverty & Human Development Initiative (OPHI); 2007 [cited 2025 13]. Available from: <https://ora.ox.ac.uk/objects/uuid:872ac1c6-ef22-4c73-b933-43340dd01eb7>
21. Torabi AJ, Mshelbwala FS, Hugenberg D, Kovacs RJ, Kreutz RP. Social deprivation index and ischemic events after percutaneous coronary intervention in patients with diabetes mellitus. *Cathet Cardio Intervent* 2022 Mar.;99:1015–21. <https://doi.org/10.1002/ccd.30108>
22. Ford MM, Highfield LD. Exploring the Spatial Association between Social Deprivation and Cardiovascular Disease Mortality at the Neighborhood Level. *PLoS ONE* 2016 Jan.;11:e0146085. <https://doi.org/10.1371/journal.pone.0146085>
23. O'Lenick CR, Winquist A, Mulholland JA, Friberg MD, Chang HH, Kramer MR, et al. Assessment of neighbourhood-level socioeconomic status as a modifier of air pollution–asthma associations among children in Atlanta. *J Epidemiol Community Health* 2017 Feb.;71:129–36. <https://doi.org/10.1136/jech-2015-206530>
24. Jione SIF, Norman P. Harmonising Incompatible Datasets to Enable GIS Use to Study Non-communicable Diseases in Tonga. *Appl. Spatial Analysis* 2023 Mar.;16:33–62. <https://doi.org/10.1007/s12061-022-09466-y>
25. Nogueira H. What is happening to health in the economic downturn? A view of the Lisbon Metropolitan Area, Portugal. *Annals of Human Biology* 2016 Mar.;43:164–8. <https://doi.org/10.3109/03014460.2015.1131846>
26. Hagedoorn P, Vandenheede H, Vanthomme K, Willaert D, Gadeyne S. A cohort study into head and neck cancer mortality in Belgium (2001–11): Are individual socioeconomic differences conditional on area deprivation? *Oral Oncology* 2016 Oct.;61:76–82. <https://doi.org/10.1016/j.oraloncology.2016.08.014>
27. Choi D-W, Lee SA, Lee DW, Joo JH, Han K-T, Kim S, et al. Effect of socioeconomic deprivation on outcomes of diabetes complications in patients with type 2 diabetes mellitus: a nationwide population-based cohort study of South Korea. *BMJ Open Diab Res Care* 2020 Jul.;8:e000729. <https://doi.org/10.1136/bmjdr-2019-000729>
28. Bertin M, Chevrier C, Pelé F, Serrano-Chavez T, Cordier S, Viel J-F. Can a deprivation index be used legitimately over both urban and rural areas? *Int J Health Geogr* 2014 Dec.;13:22. <https://doi.org/10.1186/1476-072X-13-22>
29. Temam S, Varraso R, Pernet C, Sanchez M, Affret A, Jacquemin B, et al. Ability of ecological deprivation indices to measure social inequalities in a French cohort. *BMC Public Health* 2017 Dec.;17:956. <https://doi.org/10.1186/s12889-017-4967-3>
30. López-De Fede A, Stewart JE, Hardin JW, Mayfield-Smith K. Comparison of small-area deprivation measures as predictors of chronic disease burden in a low-income population. *Int J Equity Health* 2016 Jun.;15:89. <https://doi.org/10.1186/s12939-016-0378-9>

31. Noble M, Wright G, Smith G, Dibben C. Measuring Multiple Deprivation at the Small-Area Level. *Environ Plan A* 2006 Jan.;38:169–85. <https://doi.org/10.1068/a37168>
32. Allik M, Leyland A, Travassos Ichihara MY, Dundas R. Creating small-area deprivation indices: a guide for stages and options. *J Epidemiol Community Health* 2020 Jan.;74:20–5. <https://doi.org/10.1136/jech-2019-213255>
33. Allik M, Ramos D, Agranonik M, Pinto Júnior EP, Ichihara MY, Barreto ML, et al. Developing a Small-Area Deprivation Measure for Brazil [Internet]. University of Glasgow; 2020 [cited 2024 16]. Available from: <https://eprints.gla.ac.uk/215898/>. <https://doi.org/10.36399/gla.pubs.215898>
34. Carr-Hill R, Chalmers-Dixon P, Lin J. THE PUBLIC HEALTH OBSERVATORY HANDBOOK OF HEALTH INEQUALITIES MEASUREMENT [Internet]. SEPHO; 2005 [cited 2024 29]. Available from: <http://drum.lib.umd.edu/handle/1903/22963>. <https://doi.org/10.13016/DCND-EXCN>
35. Domínguez-Berjón MF, Borrell C, Cano-Serral G, Esnaola S, Nolasco A, Pasarín MI, et al. Constructing a deprivation index based on census data in large Spanish cities (the MEDEA project). *Gaceta Sanitaria* 2008 May; <https://doi.org/10.1590/s0213-91112008000300002>
36. Clare Salmond, Salmond C, Peter Crampton, Frances Sutton, Crampton P, Sutton F. NZDep91: A New Zealand index of deprivation. *Australian and New Zealand Journal of Public Health* 1998 Dec.;22:835–7. <https://doi.org/10.1111/j.1467-842x.1998.tb01505.x>
37. World Bank Open Data [Internet]. World Bank Open Data [cited 2024 13]; Available from: <https://data.worldbank.org>
38. Instituto Nacional de Estadísticas y Censos. Datos Censo Ecuador 2022 [Internet]. Censo Ecuador [cited 2024 22]; Available from: <https://www.censoecuador.gob.ec/data-censo-ecuador/>
39. Instituto Nacional de Estadísticas y Censos. Censo de Población y Vivienda 2010 [Internet]. [cited 2024 2]; Available from: <https://www.ecuadorencifras.gob.ec/base-de-datos-censo-de-poblacion-y-vivienda-2010/>
40. Allik M, Brown D, Dundas R, Leyland AH. Developing a new small-area measure of deprivation using 2001 and 2011 census data from Scotland. *Health & Place* 2016 May;39:122–30. <https://doi.org/10.1016/j.healthplace.2016.03.006>
41. I. T. Jolliffe. Principal Component Analysis [Internet]. New York: Springer-Verlag; 2002 [cited 2025 17]. Available from: <http://link.springer.com/10.1007/b98835>. <https://doi.org/10.1007/b98835>
42. J. E. Jackson. A user's guide to principal components [Internet]. John Wiley & Sons, Ltd; 1991 [cited 2025 17]. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1002/0471725331.ch9>. <https://doi.org/10.1002/0471725331.ch9>
43. English indices of deprivation 2019: technical report - GOV.UK [Internet]. [cited 2024 10]; Available from: <https://www.gov.uk/government/publications/english-indices-of-deprivation-2019-technical-report>
44. Pampalon R, Hamel D, Gamache P, Simpson A, Philibert M. Validation of a deprivation index for public health: a complex exercise illustrated by the Quebec index. *Chronic Dis Inj Can* 2014 Feb.;34:12–22. <https://doi.org/10.24095/hpcdp.34.1.03>
45. Schlottheuber A, Hosseinpoor AR. Summary Measures of Health Inequality: A Review of Existing Measures and Their Application. *Int J Environ Res Public Health* 2022 Mar.;19:3697. <https://doi.org/10.3390/ijerph19063697>
46. Brown D, Allik M, Dundas R, Leyland AH. Carstairs Scores for Scottish Postcode Sectors, Datazones and Output Areas from the 2011 Census. MRC/CSO Social and Public Health Sciences Unit: University of Glasgow;; 2014.
47. Carstairs V. Deprivation indices: their interpretation and use in relation to health. *Journal of Epidemiology & Community Health* 1995 Dec.;49:S3–8. https://doi.org/10.1136/jech.49.Suppl_2.S3
48. Krieger N, Chen JT, Waterman PD, Soobader M-J, Subramanian SV, Carson R. Geocoding and Monitoring of US Socioeconomic Inequalities in Mortality and Cancer Incidence: Does the Choice of Area-based Measure and Geographic Level Matter?: The Public Health Disparities Geocoding Project. *American Journal of Epidemiology* 2002 Sep.;156:471–82. <https://doi.org/10.1093/aje/kwf068>
49. Lian M, Struthers J, Liu Y. Statistical Assessment of Neighborhood Socioeconomic Deprivation Environment in Spatial Epidemiologic Studies. *Open J Stat* 2016 Jun.;6:436–42. <https://doi.org/10.4236/ojs.2016.63039>
50. Lamnisos D., Lambrianidou G., Middleton N. Small-area socioeconomic deprivation indices in Cyprus: development and association with premature mortality. *BMC Public Health* 2019;19:627. <https://doi.org/10.1186/s12889-019-6973-0>
51. Bertin M, Chevrier C, Pelé F, Serrano-Chavez T, Cordier S, Viel J-F. Can a deprivation index be used legitimately over both urban and rural areas? *International Journal of Health Geographics* 2014 Jun.;13:22. <https://doi.org/10.1186/1476-072X-13-22>
52. Martin D, Brigham P, Roderick P, Barnett S, Diamond I. The (mis)Representation of Rural Deprivation. *Environ Plan A* 2000 Apr.;32:735–51. <https://doi.org/10.1068/a32130>

53. Gilthorpe MS, Wilson RC. Rural/urban differences in the association between deprivation and healthcare utilisation. *Soc Sci Med* 2003 Dec.;57:2055–63. [https://doi.org/10.1016/s0277-9536\(03\)00071-6](https://doi.org/10.1016/s0277-9536(03)00071-6)
54. Fecht D, Jones A, Hill T, Lindfield T, Thomson R, Hansell AL, et al. Inequalities in rural communities: adapting national deprivation indices for rural settings. *J Public Health (Oxf)* 2018 Jun.;40:419–25. <https://doi.org/10.1093/pubmed/idx048>
55. Havard S, Deguen S, Bodin J, Louis K, Laurent O, Bard D. A small-area index of socioeconomic deprivation to capture health inequalities in France. *Soc Sci Med* 2008 Dec.;67:2007–16. <https://doi.org/10.1016/j.socscimed.2008.09.031>
56. Lalloue B., Monnez J.-M., Padilla C., Kihal W., Le Meur N., Zmirou-Navier D., et al. A statistical procedure to create a neighborhood socioeconomic index for health inequalities analysis. *Int. J. Equity Health* 2013;12:21. <https://doi.org/10.1186/1475-9276-12-21>
57. Messer LC, Laraia BA, Kaufman JS, Eyster J, Holzman C, Culhane J, et al. The development of a standardized neighborhood deprivation index. *J Urban Health* 2006 Nov.;83:1041–62. <https://doi.org/10.1007/s11524-006-9094-x>
58. Sánchez-Cantalejo C, Ocana-Riola R, Fernández-Ajuria A. Deprivation index for small areas in Spain. *Soc Indic Res* 2008 Nov.;89:259–73. <https://doi.org/10.1007/s11205-007-9114-6>
59. Robinson WS. Ecological Correlations and the Behavior of Individuals. *American Sociological Review* 1950;15:351–7. <https://doi.org/10.2307/2087176>
60. Winzar H. The Ecological Fallacy: How to Spot One and Tips on how to Use One to Your Advantage. *Australasian Marketing Journal* 2015 Feb.;23:86–92. <https://doi.org/10.1016/j.ausmj.2014.12.002>
61. McCall SJ, Bhattacharya S, Okpo E, Macfarlane GJ. Evaluating the social determinants of teenage pregnancy: a temporal analysis using a UK obstetric database from 1950 to 2010. *J Epidemiol Community Health* 2015 Jan.;69:49–54. <https://doi.org/10.1136/jech-2014-204214>
62. Fernandes CM, Conceição GM de S, Silva ZP da, Nampo FK, Chiaravalloti Neto F. Socioeconomic factors increase the risk of teenage pregnancy: spatial and temporal analysis in a Brazilian municipality. *Rev Bras Epidemiol* 2024;27:e240040. <https://doi.org/10.1590/1980-549720240040>
63. Gordon D. Census based deprivation indices: their weighting and validation. *Journal of Epidemiology & Community Health* 1995 Dec.;49:S39–44. https://doi.org/10.1136/jech.49.Suppl_2.S39
64. Norman P, Berrie L, Exeter DJ. Calculating a deprivation index using census data. *Australian Population Studies* 2019 May;3:30–9. <https://scholar.archive.org/fatcat/release/fhldfzjvrbidagh4q6fcz2tii>
65. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic Status in Health Research: One Size Does Not Fit All. *JAMA* 2005 Dec.;294:2879. <https://doi.org/10.1001/jama.294.22.2879>
66. Krieger N, Williams DR, Moss NE. Measuring Social Class in US Public Health Research: Concepts, Methodologies, and Guidelines. *Annual Review of Public Health* 1997;18:341–78. <https://doi.org/10.1146/annurev.publhealth.18.1.341>

Abbreviations

EDI:	Ecuadorian deprivation index
GIS:	Geographic Information System
IMD:	English Index of Multiple Deprivation
INEC:	Ecuadorian National Institute of Statistics and Census
KMO:	Kasier-Meyer-Olkin test
PCA:	Principal Component Analysis
RII:	Relative index of inequality
SD:	Standard deviation
SEDHI:	Unit on the Social and Environmental Determinants of Health Inequalities
SII:	Slope index of inequality
WHO:	World Health Organization

