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A small area deprivation index for monitoring and evaluating health inequalities in a diverse, low and middle income country: the Índice Brasileiro de Privação (IBP)

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Abstract

Introduction

Monitoring and addressing health inequalities is important. However, socioeconomic variables are usually unavailable within health datasets. Area deprivation measures provide access to open-source reliable socioeconomic data within low/middle-income countries and can contribute to the monitoring of the Sustainable Development Goals and assessing the growing burden of health inequalities.

Objective

To create a small-area deprivation measure for the whole of Brazil - the Brazilian Deprivation Index (Índice Brasileiro de Privação - IBP),

Methods

Using Census Sector data (mean population size=615) from the most recently available Brazilian Demographic Census (2010), variables measuring literacy, household income and housing conditions were standardised using z-scores and summed into a single measure. The IBP was validated using regional small-area measures of vulnerability: Belo Horizonte's Health Vulnerability Index (IVS) and São Paulo's Social Vulnerability Index (IPVS). Mortality data from Minas Gerais were used to estimate age-standardised mortality rates (ASMR) by ill-defined causes across IBP deprivation quintiles.

Results

The IBP was created for 303,218 (97.8%) census sectors (99.7% population). Substantial regional variation in deprivation was found using the IBP measure, with higher deprivation in rural than urban areas. The IBP was correlated with the other indicators used for validation: the IVS ($r = 0.96$) and the IPVS ($r = 0.68$). We found gradients across the ill-defined causes ASMR, in Minas Gerais mortality was 2.6 higher in the most deprived quintile of IBP, compared with the least deprived. Main challenges in creating a deprivation measure for LMICs and possible solutions are demonstrated.

Conclusion

A small area deprivation index was created for Brazil, a large and highly diverse middle-income country. The IBP improves our understanding and monitoring of inequalities, serving as a valuable tool for informing targeted public policies. Although the index is based on Brazil's specific context, the challenges faced, and the strategies implemented to tackle them are relevant for other low- and middle-income countries aiming to develop similar tools.

Key words

deprivation index; inequalities; mortality monitoring; health policy

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Introduction

The unfair and avoidable nature of health inequalities has been well documented in the academic literature and in policy documents [1]. Health inequalities are present in all societies, but the level of this health gap between the poorest and the wealthiest varies considerably across nations [2]. In order to monitor health inequalities, a measure of socioeconomic position (SEP) is required within health datasets. These measures are often lacking at the individual level but as address is usually well recorded, ecological measures of SEP can be used as an alternative. A further advantage of using an ecological measure of SEP is that multidimensional aspects can also be captured, providing useful insights beyond the individual level, or when individual data is unavailable.

Deprivation is understood as the observed disadvantage of a group of people relative to the society as a whole, such as the lack of goods common to the society [3]. Deprivation measures provide a numeric representation of this complex and multidimensional concept. In developed nations, area deprivation measures have been used for decades to highlight and track the temporal and spatial patterning of material well-being and socioeconomic inequalities in health [4–11]. In the last few years, these measures have also been developed for countries that have in recent decades been classified as low- and middle-income countries (LMICs), including Chile [12], Ecuador [13], and South Africa [14].

To monitor social inequalities and to understand their impact on health we need to be able to measure poverty and inequalities accurately in a consistent way across the whole country. In general, the measures that track social and economic inequalities across Brazil use municipal-level data [15–17]. However, municipalities are large and diverse, and an overall high level of wealth may mask smaller pockets of severe poverty. Aggregate data often hides disparities within municipalities. Measures of social and economic position that were developed for smaller geographic areas, like census sectors, are restricted to a single municipality [18] or state [19]. Furthermore, the available measures differ between municipalities in the concepts measured and the indicator variables used to calculate them. For these reasons a standardised small-area index is essential for accurately capturing deprivation and health inequalities throughout Brazil, making it an important tool for policymakers. The aim of this article is to introduce the Brazilian Deprivation Index (Índice Brasileiro de Privação – IBP), a small-area deprivation measure developed for the whole of Brazil. We show how this measure can improve our understanding of inequalities in health and in material deprivation, and how it can aid policy making. We also summarise challenges specific to LMIC in developing these measures and discuss potential solutions to overcome these.

Methods

Creation of IBP – data, selection of variables and statistical analysis

We used data from the last available Brazilian Demographic Census in 2010 and used the census sectors (CS) as the units

of analysis [20]. CS are contiguous areas that respect political and administrative boundaries, and the legal framework [20]. Meaning that all CS are defined within the official limits of municipalities and states, making regional, municipal and state level comparisons consistent with those of other official data sources.

The Brazilian Census basic questionnaire, which all households complete, covers a wide range of variables covering the range of social determinants of health. These broadly include the commonly used domains in most deprivation measures [21], such as material wealth (e.g. car ownership, income); indicators of socioeconomic position (SEP) (e.g. education, literacy, occupation, employment); and housing conditions (e.g. overcrowding, home ownership, renting from a public authority). For each of these domains, we considered a number of different variables and definitions and selected indicators based on previous literature in the field [21, 22]. The process of selecting variables and the methodological decisions are described in detail in the IBP Technical Report [23]. We have also summarised the main challenges of creating a deprivation measure for a very diverse LMIC such as Brazil and the possible solutions to these in Box 1.

In total, we considered 14 different indicators, reflecting material wealth, education, housing conditions and neighbourhood characteristics. Indicators needed to be available for all CS, asked of all private households, and display a reasonable empirical variation across CS. Furthermore, they are consistently understood as relevant aspects in previous studies on poverty, social development and health inequalities in the Brazilian context [21, 22]. For income, the choice of variables was varied, but for literacy rates and housing conditions it was much more limited. The different literacy and housing variables also had low variability in values across Brazil compared to data on income. Despite some limitations, the three domains together meet many of the desirable qualities of deprivation indicators: they are provided consistently for small areas across Brazil, are conceptually sound and capture different aspects of deprivation. Having selected a small number of potential deprivation indicators for each of the three domains, the final choice was made by taking account of correlations between the indicators across Brazil and by regions [23].

The three variables included in the final measure were:

- percentage of households with per capita income equal or below 1/2 minimum wage;
- percentage of people who are not literate, aged 7 or over;
- average of the percentage of people with inadequate access to sewage, water, garbage collection, and no toilet and bath/shower.

Inadequate access to sewage is defined as a lack of connection to either a sewage network or a septic tank. Inadequate access to water refers to those without a supply from either a water network or a well. Inadequate access to garbage disposal is defined as situations where waste is not collected by a service provider, which means it is burned, buried, discarded in wastelands or public spaces, dumped into rivers, lakes, or seas, or disposed of through other inappropriate

Box 1: Challenges of developing and using small area indices in LMIC

Developing small-area measures

Challenge	Implications	Solution and interpretation
Inaccessible or difficult to access population groups and variation in data collection across these different population groups.	Data collection among some indigenous people, homeless or those living in slum neighbourhoods (e.g. <i>favelas</i>) may be more limited. The 2010 Brazilian census was the first to collect data on indigenous people. But data on housing characteristics (access to amenities and services) was not collected for people living in improvised households, i.e. in buildings not built for residential use (e.g. warehouses, tents).	To include people in improvised households in the housing domain we assumed that living in an improvised household indicates poor housing conditions. In calculating the percent experiencing poor housing, people in improvised households were able to be included in both the numerator and denominator, under the assumption they lacked access to amenity or services.
Known very large differences in living conditions between and within regions, metropolitan areas, population groups and across the urban-rural divide.	Indicators of deprivation need to be meaningful and capture deprivation for the entire population. However, when population groups experience very different living conditions placing them on a single scale can be challenging. Income differences between regions are very large and deciding on a cut-off that would equally measure income deprivation in the north and in the south is difficult. In addition, in urban areas lack of access to sewage or water network can indicate deprivation, but in rural areas access to septic tanks or wells can be the norm.	We balanced between variability within and between regions and population groups. Septic tanks and wells were included among adequate housing across Brazil to account for housing norms and increase variation in the indicator in rural areas (mostly in the north). This slightly decreased variation in housing deprivation in the urban south. Income deprivation cut-off was set high to increase variability in the indicator in the south. This meant that areas in the north show greater clustering at high levels of income deprivation.
Bimodal distributions in some indicators.	Related to the mentioned challenge of vast regional differences, many housing characteristic variables had bimodal distributions with values clustered at extremes of 0% and 100%. Restricted variability limits the ability of an indicator (and the measure) to discriminate between deprivation levels.	We used four separate housing characteristics (access to bathroom/toilet, garbage collection, adequate sewage disposal and water supply) and averaged across the indicators to calculate the housing deprivation domain. The combined housing indicator had substantially higher variation compared to the individual variables. Without additional data, variation cannot be increased. The exact numeric values of the deprivation measure should always be treated as estimates with uncertainty and using deprivation categories (deciles or quintiles) can provide more robust comparisons between individual small areas.
Maximum and minimum values of the combined measure were observed in a small proportion of CS.	In some census sectors (CS) the indicators did not pick up deprivation on any of the domains while in others all people in the sectors were deprived across all domains. This may indicate an underestimation of the tail ends of the distribution and the “true” level and range of deprivation.	We prioritised increasing variability in domains and good conceptual fit over including more variables of the same kind. For example, housing data were more limited and had lower variability compared to income data but were included to cover a different aspect of deprivation. We were able to cover three domains of material deprivation (income, literacy, and housing).
The census basic questionnaire that covers the whole population only includes a few questions, limiting the choice of variables available at CS level.	In LMICs it may not be feasible to use long questionnaires for the whole census population, limiting the choice of variables. This makes it more difficult to select deprivation indicators that meet all the desired criteria (e.g. conceptual fit, empirical variation, cover different domains) of material deprivation.	The final measure is essentially an average of the indicators and all domains were given the same weight. This results in diverging values giving an average score. Subsequent analysis of the data and contextual knowledge should improve understanding as to whether this is an artefact of the data or an accurate description of deprivation in these areas.
Large differences in indicator values for some specific small area.	For some small areas, deprivation indicators diverge substantially – an area can be very deprived in the housing domain, but not deprived in the income or literacy domains. Large differences in indicator values may cast doubt upon the reliability of the indicators in measuring the domains of the same concept.	

Continued

Box 1: Continued

Developing small-area measures

Challenge	Implications	Solution and interpretation
Large variation in the population size of small areas.	CS population size varies from 1 to 5315 ($\bar{x}=615$; $sd=354$), having implications for uncertainty in estimating deprivation. For the smallest areas this increases uncertainty about “true” deprivation. For the larger areas this may mean increased heterogeneity among the population, increasing the potential for a mismatch between individual and area deprivation.	As part of good practice of developing small-area measures, confidence intervals for the deprivation measure were provided and areas of high uncertainty are flagged in the data. Population size for all areas is also provided in the data and this can be used to assess heterogeneity.
Levels of uncertainty in the deprivation measure are very high for some areas.	Related to the small population size and diverging levels of deprivation in individual indicators in some CS, uncertainty in measured deprivation is high* in 4.5% of the areas, affecting 2.5% of the population. For these areas, the estimated deprivation score and level (decile, quintile) is unreliable. <i>*For a definition of high uncertainty see the technical report by Allik et al (2020).</i>	The deprivation measure is a population tool for national and larger regional analysis rather than making decisions about individual areas. We recommend including areas with high uncertainty in research as they affect a small proportion of the population. When making policy recommendations or decisions on resource allocation, the deprivation measure should be used as part of a toolkit. Research conclusions and policy decisions should be made for groups of small areas and not for individual sectors.
Validation of the deprivation measure is difficult in the absence of or with limited tradition of developing small-area measures, and with few data sources.	As part of good practice, small-area measures should be validated to provide evidence that they capture the concept they are intended to measure. In countries with a long history of developing small-area measures and good access to different data sources (e.g. to nationwide administrative or geospatial data) this can be easier by comparing the developed measure to historic measures or by using different data sources. In addition, deprivation measures can be validated by seeing how well they can predict inequalities in health. This would require access to health data at the small area level. In some countries neither of these options may be possible.	Different strategies of validation can be combined. For example, to provide validation at the CS level, we compared the deprivation measure to other similar measures within municipalities and states where this was possible. To provide validation for the whole of Brazil, we calculated the deprivation measure for municipalities and compared this to other municipal development and vulnerability measures and health outcomes available for the whole country.

Using small-area measures

Challenge	Implications	Solution and interpretation
Making data accessible for different audiences.	The size of the data (over 300,000 small areas) can mean that commonly used data visualisation and accessibility tools (e.g. address/postcode to sector id/deprivation look-up tables) are not easy or feasible to implement.	Accessibility tools may need to be built regionally or by states to manage the size of the data. Currently the data are accessible as a single csv file with no direct link to an address or a physical location on a map. This requires the user to know the CS of a physical location to look up its deprivation level.
To assess socioeconomic inequalities in health, health data need to be available and coded for the same small areas.	High quality address data need to be present in mortality and health records to add small-area identifiers to these data (e.g. by using geo-coding algorithms). Our results of geocoding mortality data showed differential results by deprivation – areas of high deprivation had lower geocoding rates and vice versa. This could lead to biased estimates of inequalities in mortality across Brazil.	This highlights priorities for future work, such as improving the recording of health data. The initial analysis of inequalities in mortality may need to focus on regions or states with known better data quality. As these are likely to be wealthier regions, they are likely to underestimate inequalities for the whole of Brazil.

Continued

Box 1: Continued

Using small-area measures		
Challenge	Implications	Solution and interpretation
Stability in indicators over time can be more difficult to achieve in LMICs if they experience rapid socioeconomic development, such as vastly improved access to electricity, sanitation, or basic education.	It is important to consider how indicators of deprivation might change in the near future to prevent the measure becoming obsolete in a few years. Similarly, the frequency with which the data are updated (e.g. the census is repeated only every 10 years) will have implications for how quickly the measure can lose meaning.	The meaning of deprivation is always time and context specific. The focus should be on covering the same domains rather than indicators. Domains of material deprivation will be more constant while the exact indicators are bound to change over time. Our aim has also been to measure relative not absolute deprivation, and for this reason changes in the indicators will not affect the interpretation of how some areas compare to others in terms of deprivation. The exact numeric values of the deprivation measure should, however, not be compared across time.

methods. We have selected age seven as the cut-off since this aligns with the mandatory school age in Brazil, making it a more accurate indicator of access to education and subsequent deprivation.

The three variables were combined by standardising them using z-scores and then summing these into a single measure, with all three equally weighted [24]. The combined measure is the Brazilian Index of Deprivation (Índice Brasileiro de Privação, IBP), with high values of IBP indicating high, and low values low deprivation. We compared the IBP to indices with the same indicators obtained using other methods of combining variables (e.g. principal component analysis) and found virtually no difference in the results (Appendix 1) [23]. The IBP measure was also categorised into population weighted vigintiles, deciles and quintiles such that across Brazil each category includes the same proportion of population (5% in each vigintile, 10% in each decile and 20% in quintiles).

Uncertainty in the estimated level of deprivation was assessed using two different approaches described previously (random weights and random numerators) [24]. We defined high uncertainty as more than one category disagreement between the decile of the estimated measure and the decile between a 95% confidence interval. This implies that if a sector's confidence interval permits classification two (or more) deciles above or below its point estimate, it is seen as having high uncertainty. The IBP measure and the uncertainty estimates are freely available for all researchers and policymakers to use from: <https://cidacs.bahia.fiocruz.br/ibp/painel-en/>.

Validation with existing small area measures

Two existing small area measures of vulnerability in Brazil were chosen to validate the IBP: the Health Vulnerability Index (IVS) [18] created for the Belo Horizonte municipality, and the Social Vulnerability Index (IPVS) created for the state of São Paulo [19]. We compared the correlation and deprivation categories between the IBP with the IVS and the IPVS for the census sectors.

To validate the IBP across Brazil, we calculated the IBP at the municipal level using the exact same method as described

above for census sectors. We then compared the municipal IBP to the Municipal Human Development Index (MHDI) [16] and the Index of Social Vulnerability (MIVS) [15] using correlation. To provide further validity, we correlated the municipal IBP to infant mortality, probability of survival, and life expectancy at birth (all available at the municipal level) [16].

Validation with mortality statistics

The original intention was to validate the deprivation measure using small-area mortality data for 2009–2012 (around the 2010 Census year) from the Mortality Information System (Sistema de Informação sobre Mortalidade, SIM). We encountered several issues; the first issue was the mortality datafile for 2011 was corrupted and we could not use this year. While recording of mortality has improved over years, under-registration of deaths remained a source of bias. As under-registration is positively correlated to deprivation, this may lead to significantly underestimated inequalities in mortality. In addition, to use the IBP to assess inequalities in mortality, each death needs to be assigned to a CS, and then linked to the IBP. However, the address of the deceased was not always well recorded, and this varied by state and municipality, and was also correlated with deprivation.

However, the quality issues in SIM also represent an opportunity to use IBP to study these problems. We explored the relationship between deprivation and the rate of ill-defined causes of death as they can be considered an important indicator reflecting barriers in access to health services and deficiencies in the quality of health care [25]. To ensure a high proportion of deaths assigned to a CS and minimise selection bias of deaths according to deprivation, we restricted this analysis to the State of Minas Gerais, located in the southern region and with a good range of deprivation across IBP quintiles.

To assess differences in mortality data quality according to IBP, we calculated the Age Standardised Mortality Rates (ASMR) for ill-defined causes of death for each quintile of deprivation using the World Health Organization population structure as the reference. Deaths included in this analysis occurred in 2009, 2010 and 2012 in people resident in Minas

Gerais. In this period 366,311 deaths were recorded in Minas Gerais, with 86.1% assigned to a CS (84.5% when considering deaths from ill-defined causes). We also estimate the SMR due to ill-defined cause of death for Belo Horizonte, the capital of Minas Gerais State, to allow comparison of the rates using the IVS and the IBP.

Results

Description of census sectors for the IBP

In 2010, there were available information for 310,120 CS in Brazil, (average population size 615.1, $sd=354.3$). However, the variation in CS population size was quite large, with the largest sector including 5,315 people and the smallest only one person. Census sectors tend to be more homogeneous in areas with greater population density and less homogeneous in areas of low density.

A small number of CS were excluded from the analysis due to statistical disclosure control (SDC) applied by the Brazilian Institute of Geography and Statistics (IBGE) (6,302 or 2% census sectors, 0.2% of the total population), and CS comprised of people living in communal residences (e.g. prisons, care homes) and no private households were also removed (600 or 0.2% census sectors, fewer than 0.1% of total population). The IBP was calculated for a total of 303,218 (97.8%) census sectors, covering 190,145,077 (99.7%) people.

Deprivation in Brazil

Table 1 and Figure 1 show the population distribution across IBP deciles by region and urban-rural classification. By design, across Brazil each decile includes 10% of the household population, but this varies substantially within regions. The percent of people in the least deprived deciles (deciles 1-4) is 5-8 times higher in the South and Southeast compared to the North and Northeast. The Central-West region has a high proportion of individuals in deciles of average and moderate deprivation (deciles 5-7). The regional differences in deprivation deciles are visualised on the map in Figure 2. The most deprived deciles are concentrated in the Northeast and North, with the least deprived in the Southeast and South.

Over half the people (53%) who live in rural CS, live in the most deprived decile and another 21% live in the 9th decile. Only 10% of people who live in urban areas are in the very deprived 9th or 10th deciles.

Uncertainty in measurement

Table 2 shows the uncertainty of CS overall and by region. In total 4.5% of CS and 2.5% of the population are affected by high uncertainty in the deprivation measure. Regional variation with high uncertainty in estimating deprivation is more notable in South and Central-West (Table 2). Common to these two regions is lower than average CS population size compared to the other regions (529.9 in South and 587.7 in Central-West, compared to 660.7 in Northeast) and poorer correlation of the income and literacy domains to the housing domain ($r=0.59$ in South and Central-West, $r=0.68$ in Northeast). Areas of high uncertainty South and Central-West often have

low levels of income and literacy deprivation but relatively high levels of housing deprivation. This results in average levels of deprivation of the IBP, but small changes to the weight of the indicators could increase or decrease the estimated deprivation level. In the published dataset these areas have been indicated with a flag and all analysis using the measure should be aware of and possibly exclude these areas.

Validation with existing small area measures

The IBP is highly correlated with the IVS in Belo Horizonte ($r=0.96$) and has a fairly strong association with the socio-economic domain of the IPVS in São Paulo ($r=0.68$). Table 3 provides a comparison of quintiles of IBP with IVS and IPVS. Despite the included variables and categorisations of IBP, IVS and IPVS being different, the three measures show good agreement and highlight that people in Belo Horizonte and São Paulo are more likely to live in areas of low deprivation and vulnerability, though both municipalities also have pockets of severe deprivation and vulnerability.

Table 3 shows the proportion of the population in Belo Horizonte and São Paulo by quintile of IBP and categories of IVS (Belo Horizonte) and IPVS (São Paulo). The proportion of the population in the low IVS category is 33.7% this compares to 52.8% in IPVS, indicating that São Paulo is better/less vulnerable than Belo Horizonte. However, using the IBP, we can directly compare municipalities as Belo Horizonte and São Paulo. The proportion of the population in the lowest IBP quintile is 52.6% for Belo Horizonte compared to 41.4% for São Paulo, indicating that Belo Horizonte is less deprived than São Paulo.

To provide validation across Brazil, the IBP was compared to other similar measures at the municipal level. The municipal IBP was highly correlated to the MHDl and MIVS ($r>0.88$ for both). The municipal IBP was also highly correlated with infant mortality ($r=0.81$) and life expectancy ($r=-0.84$). The correlations for these health outcomes were somewhat lower for MIVS ($r<0.80$). For the full MHDl (includes life expectancy), correlations with infant mortality and life expectancy were the same as for IBP but excluding life expectancy from MHDl reduced the correlation coefficients slightly ($r<0.80$).

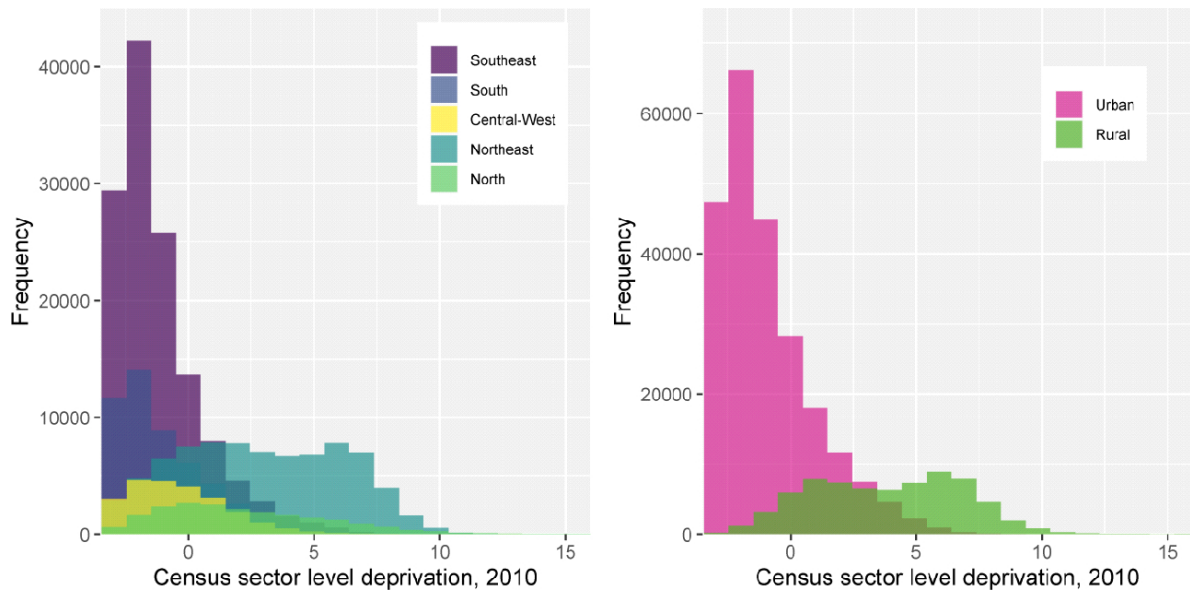
Deprivation and ill-defined causes of death

Table 4 shows there were a total of 29,465 (9.52%) deaths classified as ill-defined cause in Minas Gerais in 2009-2012 registered and geocoded. The ill-defined cause SMR was 2.6 higher in the most deprived quintile of IBP (70.61 per 100,000 inhabitants), compared with the lowest deprived (27.58 per 100,000 inhabitants). There is a gradient across the quintiles of deprivation. The Table also shows the ill-defined causes of death for Belo Horizonte (within Minas Gerais) by IBP and IVS. Both indexes show a gradient between the level of deprivation/vulnerability and mortality rates, with mortality increasing as vulnerability/deprivation increases.

Table 1: Population distribution in percentages by region, urban-rural classification and IBP decile, 2010

	Low deprivation					High deprivation					Total
	1	2	3	4	5	6	7	8	9	10	
Brazil	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	100
Southeast	14.4	14.9	15.1	14.7	13.1	10.9	7.8	5.1	3.0	1.1	100
South	16.9	16.1	13.8	12.1	11.5	10.4	8.9	6.9	3.2	0.3	100
Central-West	8.9	8.0	9.2	10.4	12.5	14.6	17.2	12.2	5.6	1.5	100
Northeast	2.6	2.3	2.7	3.5	5.0	7.3	10.6	16.0	22.4	27.6	100
North	1.7	2.5	3.3	4.3	6.3	9.8	14.5	17.9	19.6	20.2	100
Rural	0.1	0.3	0.5	1.0	1.8	3.6	6.9	12.1	20.5	53.3	100
Urban	11.8	11.8	11.8	11.7	11.5	11.2	10.6	9.6	8.1	2.0	100

Figure 1: Distribution of IBP at the census sector level by region and urban-rural classification 2010



High values of the IBP indicate high deprivation and low value of IBP low deprivation.

Table 2: Number of census sectors with high uncertainty by decile and region

	Low deprivation					High deprivation					Total	
	1	2	3	4	5	6	7	8	9	10	N	%
Brazil N CS	598	776	1278	2493	3172	2281	1872	901	271	82	13724	4.5
Brazil % CS	1.8	2.6	4.6	9.0	11.5	8.2	6.4	2.9	0.9	0.2		
Southeast	257	292	379	705	1004	873	747	351	99	13	4720	3.6
South	266	372	658	1174	1347	995	744	306	42	3	5907	11.4
Central-West	41	59	130	378	499	219	239	143	36	2	1746	7.3
Northeast	26	33	61	126	175	128	96	74	77	37	833	1
North	8	20	50	110	147	66	46	27	17	27	518	2.4
Rural	30	47	97	300	593	956	1093	544	117	42	9905	4.2
Urban	568	729	1181	2193	2579	1325	779	357	154	40	3819	5.2

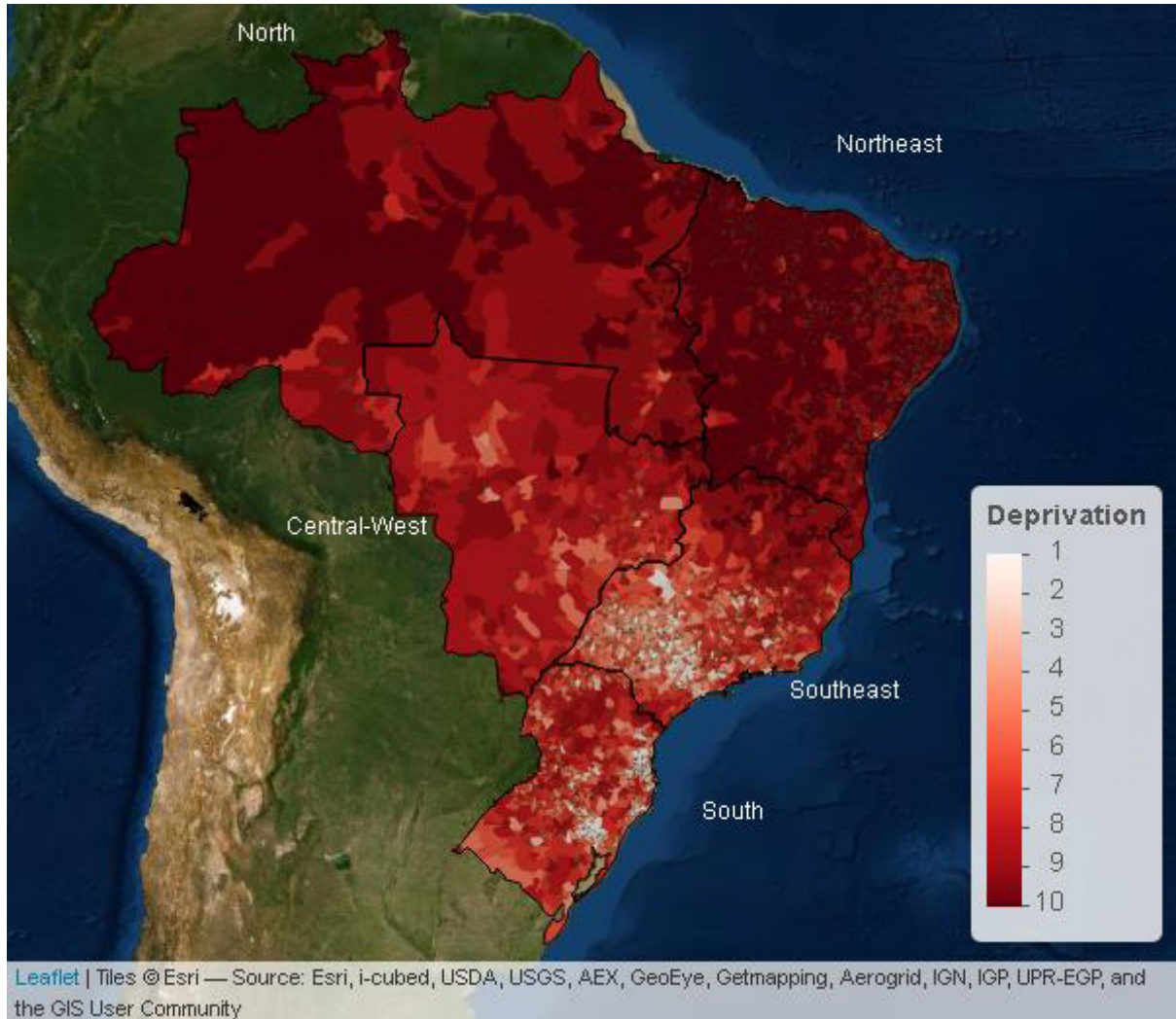
Discussion

Main findings

The IBP is the first measure of material deprivation for small areas covering the entire territory of Brazil. There is

substantial regional variation in deprivation, with the North and Northeast regions having most of their population living in areas classified as deprived (deciles 8-10) compared to the South and Southeast regions where most people live in deciles 1-4. Deprivation also varies by Census Sectors designated as urban or rural [20] with higher deprivation in rural areas.

Figure 2: IBP deciles across Brazil, 2010 (municipal measure)



High values of the IBP decile indicate high deprivation and low values of IBP decile low deprivation. We have used the municipal measure (5,565 areas) here for visualisation purposes as it was not possible to display the over 300,000 SC on a single map of Brazil. The IBP measure is freely available for all researchers and policymakers to use from: <https://cidacs.bahia.fiocruz.br/ibp/painel-en/>.

Table 3: Population distribution by deprivation and social vulnerability in the municipalities of Belo Horizonte (BH) and São Paulo (SP)

	Belo Horizonte (BH) municipality					São Paulo (SP) municipality				
IBP quintiles	1	2	3	4	5	1	2	3	4	5
N CS	2018	1023	609	174	6	8024	5067	3133	1119	68
% Population	52.6	27.4	15.8	4.1	0.1	41.4	30.9	20.0	7.3	0.4
IVS (BH)/ IPVS (SP)	Low	Medium	High	Very high	Lowest & Very low	Low	Medium	High	Very high	
N CS	1330	1460	737	303	9986	2724	2321	1259	1121	
% Population	33.7	39.9	19.1	7.3	52.8	17.2	13.6	8.9	7.5	

Measuring deprivation at census sector-level means areas of greater and lesser deprivation within the same municipality can be identified. These small locations of deprivation are masked if municipal-level measures are used. For example, the Municipality of São Paulo (population 11 million) has high municipal human development [26] and low vulnerability [27], but the IBP, a census sector-level measure, can reveal pockets

of significant deprivation. Using the IBP, we have shown that compared to Brazil as a whole, people in Belo Horizonte and São Paulo are more likely to live in areas of low deprivation and vulnerability, though both municipalities also have pockets of severe deprivation and vulnerability.

There is a tradition of creating and using indicators to study inequalities in Brazil, but the existing indicators that

Table 4: Age standardised mortality rate (ASMR) for ill-defined cause of death, by quintiles of IBP (Municipality Level) for State of Minas Gerais (2009-2012), and by levels of Social Vulnerability Index and quintiles of IBP (CS Level) for Belo Horizonte city (2009, 2010-, 2012)

State of Minas Gerais		IBP Quintiles (Municipal level)				
		1 (least deprived)	2	3	4	5 (most deprived)
% Population		19.7	25.1	24.3	18.7	12.1
Ill-defined Deaths	N	4083	6388	7144	6689	5161
	%	13.9	21.7	24.2	22.7	17.5
	ASMR (per 100,000)	27.58	42.88	54.58	64.10	70.61
Belo Horizonte		Levels of Social Vulnerability Index (IVS)				
		Low	Medium	High	Very High	
% Population		33.7	39.9	19.1	7.3	
Ill-defined Deaths	N	521	1007	600	217	
	%	22.2	42.9	25.6	9.3	
	ASMR (per 100,000)	15.54	33.40	51.57	60.55	
Belo Horizonte		IBP Quintiles (CS level)				
		1 (least deprived)	2	3	4+5 combined (most deprived)	
% Population		52.5	27.4	15.9	4.2	
Ill-defined Deaths	N	961	746	505	133	
	%	41.0	31.8	21.5	5.7	
	ASMR (per 100,000)	20.04	38.41	55.02	66.78	

measure the whole country (e.g., the Human Development Index) are only available at municipality-level. This is problematic as the population size of some municipalities is extremely large (e.g., over 1million). Other measures exist for areas smaller than municipalities (e.g., the Health Vulnerability Index for Belo Horizonte and the São Paulo Social Vulnerability Index), but they are only available for the municipalities for which they were created, and are not directly comparable. The IBP allows for direct comparisons of census sectors (and groupings such as quantiles) across the whole of Brazil. Using the IBP, we found that the proportion of people in the least deprived quintile in Belo Horizonte is higher compared to São Paulo municipality. Although very few people in either municipality live in the deprived quintiles, compared to Belo Horizonte, São Paulo has more deprived CS and people living in these areas. These types of comparisons are not possible using the IVS and IPVS as they use different variables and the categorisation of vulnerability is specific to each location, such that “Low” vulnerability in Belo Horizonte does not indicate the same level of vulnerability as “Low” in São Paulo. If we were to make comparisons across the two municipalities based on the IVS and IPVS, we may come to the potentially wrong conclusion that Belo Horizonte has more people in vulnerable areas compared to São Paulo.

Implications for LMICs

The creation of the IBP was not without its challenges and these are detailed in Box 1, along with the possible

solutions. There are challenges for both developing and using small-area deprivation measures. One of the bigger challenges remains the use of these indicators to assess socioeconomic inequalities in health. For this, it is crucial to have address data (or CS level information) recorded in health and mortality datasets. However, ensuring high-quality address data in these records can be hard in LMIC. We found geocoding algorithms gave different quality results by deprivation, leading to biased estimates of mortality inequalities across Brazil, emphasising the need for improved recording of health data. Indicators may also become out of date in LMICs much faster compared to developed nations due to rapid socioeconomic development. Therefore, considering how indicators of deprivation might change is necessary to prevent the measure from becoming obsolete. The frequency of data updates, such as the census, impacts the measure’s relevance. To maintain meaning over time, the focus should be on covering the same domains of material deprivation while exact indicators may change.

Comparison with previous studies

We followed established methods to calculate deprivation indices from Census data [21, 28]. The IBP was designed to capture material deprivation and is comprised of three indicator variables: literacy, and household income and housing conditions. Other countries with small area deprivation measures commonly use more indicator domains. For example, the New Zealand deprivation index includes information from five domains (employment, crime, health, education and

access to public services) [8] and a measure developed in South Africa uses eleven indicator variables [14]. However, the Carstairs index developed in the UK in 1991 only uses four variables (car ownership, overcrowded housing, unemployment and low social class) [11] and an index in Chile uses three (low level of education, disability and unemployment) [12]. In keeping with whole country small area indices, the variables were combined using an unweighted additive approach [11, 12], meaning the indicators contributed equally to the total. We also examined combining the indicators using Principal Component Analysis and this made very little difference to the results, therefore we preferred to use the simpler approach [23].

Limitations

The main limitations of the IBP were the number of variables and the variability of these across the CS. The IBP consists of three indicators, each capturing different aspects of material deprivation. Together, they provide a more comprehensive measure than any single indicator alone. Other weaknesses include those common to all area-based deprivation measures. The first is ecological fallacy: individuals within the same area may have varying socioeconomic circumstances, and area-level measures may not accurately capture these individual differences. The second is spatial heterogeneity: even though we used the CS, areas designated as deprived may contain variation in deprivation levels. Some parts of a CS may be relatively affluent while others are more deprived; as such area-level measures may not capture this spatial heterogeneity effectively. Thirdly, measures can become out of date. We used high quality Census data, but this was collected in 2010, and will not be updated until the 2022 census data are released in 2025.

Strengths

This study has a number of strengths. First, the IBP can be used as a standardised measure of inequality for a range of policies and outcomes, such as monitoring progress towards the SDGs, and it can be used to compare areas within Brazil (e.g., Belo Horizonte and São Paulo municipalities). Second, it is a measure of material deprivation and as such, does not include any health measures in the index (unlike the IVS), making it easier to avoid circularity when studying health outcomes. For the purposes of tracking socioeconomic and health inequalities, this is preferable to the concepts and measures of vulnerability or human development, which have been used previously in Brazil and other LMIC. Both poor health and mortality can be aspects of vulnerability and human development, and are often included in such indices, making these less appropriate and potentially endogenous for measuring health inequalities. The prolific use of deprivation measures internationally shows that this is a recognised concept in health inequalities research [4–14]. Third, the IBP allows monitoring patterns of social inequality where information at the individual-level is not available. Fourth, as the IBP is measured at the area level, it can be used to measure and monitor contextual effects of these areas, and where individual level SEP measures are available can be used

in conjunction with them to ascertain the relative importance of composition and context.

Implications for policy

The IBP allows assessing inequalities across the whole of Brazil. Therefore, the IBP is important for both planning and evaluating national public social policies, such as interventions of social protection (Bolsa Familia), health, education, housing (Minha Casa Minha Vida programme), and basic sanitation, of course, with the necessary caution in these inferential processes, as the measure still carries some degree of uncertainty. In addition, the IBP has the potential to be used as a stratification variable in national surveys [29] and as weighting to ensure that surveys are representative in terms of deprivation and sociodemographic characteristics [30].

Conclusion

The IBP provides a standardised measure of material deprivation, calculated at a small area-level (Census Sector) for the whole of Brazil and including literacy, household income and housing conditions indicators. The availability of this national measure allows comparisons across states and municipalities, and we have shown that there is considerable variation both within and between municipalities. By identifying localised patterns of deprivation, the IBP improves our ability to understand social and health inequalities, aiding in more equitable policy design and resource allocation. We have demonstrated it is possible to create a small area deprivation index for LMIC, which will greatly improve the measuring and monitoring of inequalities in health, mortality and other social outcomes, such as education and employment levels. The United Nations Sustainable Development Goals (SDG), especially SDG 10 reduced inequalities, will only be achieved if governments introduce policies that mitigate the impact of economic recessions. The measurement of deprivation plays a key role in monitoring socioeconomic and health inequalities, achieving progress towards SDGs, and securing well-being for current and future generations.

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Conflict of interests

The authors declare no conflicts of interest.

Ethics statement

The study did not require ethical approval as this is an analysis using publicly available data.

Data sharing

The Índice Brasileiro de Privação (IBP) measure is freely available for all researchers and policymakers to use from: <https://cidacs.bahia.fiocruz.br/ibp/painel-en/>. The underlying data used in the project is from the Brazilian Demographic Census in 2010. These data are available from Brazilian Institute of Geography and Statistic (IBGE).

Contributors

RD, MYI, SVK, MB, AHL conceptualised the study. RD, MAI, MAg, MYI, DR, EJ designed the methods. MAI, MAg, DR carried out the data curation. MAI, MAg, DR, EJ carried out the analysis. MAI, MYI, RD, EJ prepared and wrote the manuscript. AJFF, FJA, CT, RF-O, PR, RR, MS contributed to sections of the manuscript and were involved in reviewing and editing. RD, MYI, SVK, MB, AHL were responsible for the funding acquisition. MAI, MAg, EJ, DR have directly accessed and verified the data used in the study. All authors contributed to the writing, reviewing and editing of the manuscript.

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Appendix 1

Figure 1A: Relationship between alternative measures of IBP

