

Spatial accessibility poverty in rural areas. The case of Northeast Brazil

Highlights:

1. The study proposes an index for measuring Spatial Accessibility Poverty in rural areas of the Global South.
2. High shares of rural population do not necessarily imply in high spatial accessibility poverty at a municipality level.
3. Spatial accessibility poverty is strongly associated with deprivation of housing facilities and low population density.
4. The study shows how simple spatial data can be combined to mitigate subjectivity in social and equity appraisals of transport projects.
5. The study case concludes that Maranhão and Piauí are the two most accessibility deprived states of Northeast Brazil.

KEYWORDS: Spatial accessibility, Poverty reduction, Global South, Floating catchment area, Northeast Brazil, Rural accessibility

Abstract:

This study proposes an innovative index for measuring transport-related exclusion in rural areas caused by the lack of access to basic opportunities (e.g. healthcare, education, jobs, etc). The Spatial Accessibility Poverty (SAP) index, that is developed, is tailored for rural areas of the Global South, where spatial data is mostly scarce and such poverty dimension has been persistently neglected in quantitative studies. The paper address rural areas from Northeast Brazil in a case study, which is considered the largest pocket of rural poverty of Latin America (Coirolo and Lammert, 2008). Yet, since the SAP index requires just a fairly basic spatial dataset to be processed, it is potentially replicable globally. The core of the methodology is a gravity-based model composed of Floating Catchment Area (FCA) techniques and the Kernel Density function. The spatial information is then aggregated at a municipality level creating an index that conjugates a factor of intensity (how spatially excluded is a person from the basic opportunities?) and an extent factor (how many people are being affected by such accessibility poverty?). The findings show that high shares of rural population do not necessarily imply in high spatial accessibility poverty. Instead, other factors like deprivation of housing facilities and low population density are found strongly associated to critical SAP levels. The findings also emphasise the importance of considering sensitivity analysis and complementary factor analysis when applying the SAP index for planning and action prioritisation purposes. Considering the current gap of knowledge in this topic, this index could play a critical role to promote a new standard of transport development strongly committed in eradicating poverty.

1. INTRODUCTION

Studies addressing the multidimensional concept of poverty have shown that monetary indicators, although important, do not capture essential factors of deprivation experienced by the poor (Alkire and Seth, 2015; Narayan et al, 2000). Thus, other dimensions of poverty like education, health, and living standards have been ever more incorporated in social studies to

promote more comprehensive assessments and better policy recommendations for tackling poverty (Alkire and Foster, 2011).

Moreover, a World Bank publication has also argued based on studies in the Latin America and the Caribbean (LAC) that the primary difference between those who have escaped chronic poverty and those still trapped in it is not income, but access to essential services (Vakis et al, 2016). In fact, despite the increasing body of research dedicated to evaluate access to house facilities (e.g. electricity, sanitation, etc) and healthcare services in rural Global South (Luo et al, 2017; Nesbitt et al, 2014; Yao et 2013; Hu et al, 2013), only few notable exceptions have been dedicated to evaluating quantitatively the overall accessibility poverty in rural Global South (limi et al, 2016; Roberts et al, 2006; Sarkar and Ghosh, 2008; Lebo and Schelling, 2001).

The Rural Access Index (RAI) proposed by Roberts et al (2006) and restructured by limi et al (2016) has delivered a substantial contribution by establishing a quantitative indicator of rural accessibility from more than 170 countries. However, such an index presents only the ease of access to the rural transport network¹, which generally does not mean access to basic services. In a context where travel distances are predominantly high (Benevenuto et al, 2018) and poor people mostly live in a walking world (Porter, 2002), access to the transport network might not be a sufficient indicator to assess real accessibility in rural areas.

Moreover, when no quantitative indicators of accessibility are available to foster an equitable and inclusive transparent planning, the prioritisation of transport interventions inevitably assumes a biased, arbitrary and paternalistic fashion (Di Ciommo, 2016). The study presented in this paper attempts to support evidence-based transport planning that may mitigate the current status of subjectivity in social appraisals of transport interventions. In that sense,

¹ The RAI index estimates the share of people living farther than 2km from any all-season road

drawing upon the literature, this study constructs a Spatial Accessibility Poverty (SAP) index at a municipal level that is intended to not only overcome the shortfall of academic research but also to offer an aid for the prioritisation process of transport projects in rural areas of the Global South.

In summary, the SAP index aims at measuring transport-related exclusion in rural areas caused by the lack of access to basic facilities (e.g. health, education, shopping, financial facilities). Even though this case study is particularly tailored to the Brazilian context, it is potentially replicable to other countries with similar characteristics of spatial data and rural poverty.

2. DATA AND METHODS

The present case study focuses on the Rural Northeast Brazil context, which was once considered the least developed region of the western hemisphere (Galeano, 1972). In fact, according to the Human Development Atlas in Brazil (UNDP et al, 2010), the Northeast region accounts alone for more than half (63%) of the population surviving in extreme poverty in Brazil, approximately 7.9 million people. Moreover, the majority of these people (57%) resides in rural areas, creating what has been described as the largest pocket of rural poverty in Latin America (Coirolo and Lammert, 2008).

Since the extent of such low development pattern also covers the north part of the immediate region below (Southeast), the Brazilian Federal Government has also incorporated these municipalities within the scope of the Superintendency for the Development of the Northeast (SUDENE). Consequently, the case study presented at this study also reflects the same extended Northeast area, which is composed of a total of 1,990 municipalities.

2.1 Mapping opportunities

Although a substantial progress has been achieved in Brazil on the compilation of spatial data since 2008², the clear majority of basic facilities' (schools, healthcare centres, police stations, supermarkets, pharmacies, banks, etc) coordinates remain still unknown at a national level, especially in the rural and suburban areas (Benevenuto et al, 2018).

Nonetheless, since such opportunities as a rule are primarily concentrated within the urban centres (Benevenuto et al, 2018; IBGE, 2008; Church et al 2000), it is reasonable to assume the geolocation of each urban centre (i.e. city hall coordinates) as an aggregated proxy for public services and basic amenities' locations at a larger scale. The variety and complexity of services and amenities offered in each centre are dependent on the urban hierarchy of each centre. The present study considers the traditional centrality hierarchisation method proposed by IBGE (2008), which stratifies the Brazilian Municipalities of this case study region in five different levels of centrality (weights) as shown in Figure 1:

1. Metropolis - 6 municipalities (of 1,393 to 2,675 thousand inhabitants each)
2. Regional capital – 27 municipalities (of 134 to 1,014 thousand inhabitants each)
3. Sub-regional capital – 66 municipalities (of 23 to 334 thousand inhabitants each)
4. Zone centre - 220 municipalities (of 8 to 126 thousand inhabitants each)
5. Local centres - 1,765 municipalities (of 1 to 87 thousand inhabitants each)

² The National Spatial Data Infrastructure (INDE) was created in 2008 - <http://www.inde.gov.br/>

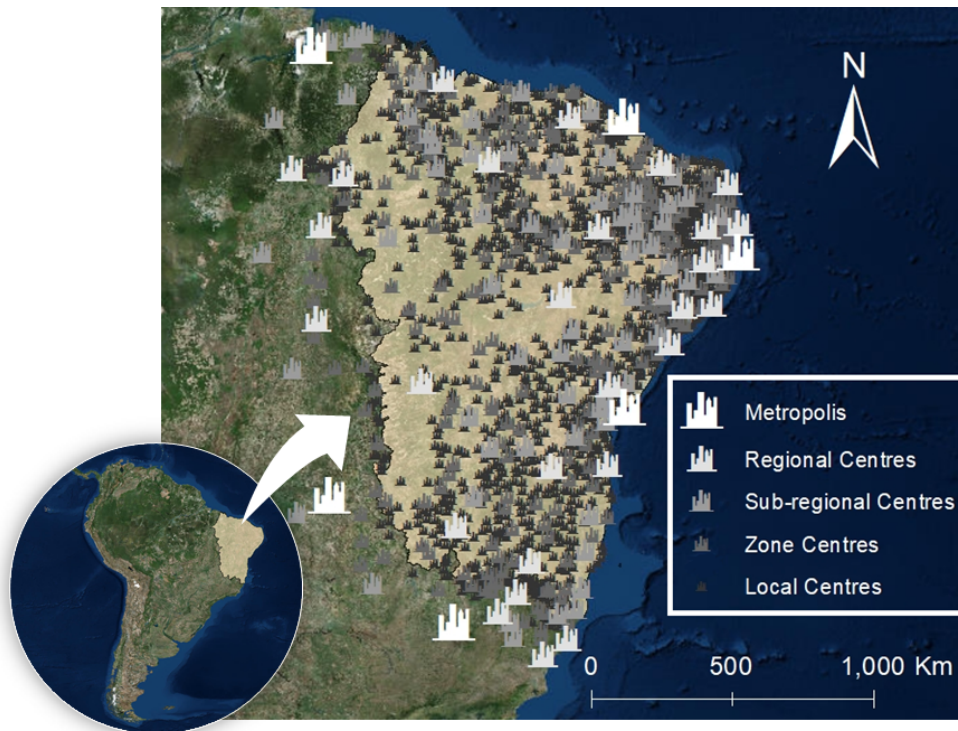


Figure 1: Urban centres in Northeast Brazil

Beyond population size, different services are taken into consideration when composing such centrality levels, for example, higher education provision, banking services, number of business offices, hospitals, coverage areas of television stations and internet, etc (IBGE, 2008). Overall, this hierarchy is mainly based on i) the number and complexity of services available in each urban centre, and ii) by the influence that each centre exerts on the surrounding municipalities (IBGE, 2008).

Even though other studies have been published since 2007 updating the regional divisions of the Country (IBGE, 2016; IBGE, 2017), they do not propose any different hierarchisation method for urban centrality. Rather, they based their population arrangements and regional divisions on the same seminal paper (IBGE, 2008), confirming that this urban hierarchisation method is still valid, until new advice is published.

2.2 The Spatial Accessibility Poverty Index

Several indices have been proposed to assess spatial accessibility by estimating catchment areas of opportunities (e.g. healthcare, jobs, primary schools, healthy food, etc), their distance decay effects, and the population attended by such Points Of Interest (POI) (Polzin et al, 2014; Schuurman et al, 2010; Geurs and van Wee, 2004). The seminal paper authored by Radke and Wu (2000) has introduced a simple and effective gravity-based measure³ aiming to achieve a fair and equal distribution of social programs. This model, later named as Two Step Floating Catchment Area (2SFCA) by Luo and Wang (2003), defines the service area of a given POI by a threshold travel time/distance while also accounting for the availability of such POI over its surrounded demands (Luo and Wang, 2003).

Later studies have introduced three ways of conceptualising the distance decay effect in this model: the continuous functions, the discrete variables, or a hybrid of these two (Wang, 2012; Dai, 2010; Luo and Qi, 2009; and Guagliardo, 2004). In the present methodology, Floating Catchment Area (FCA) techniques and the Kernel Density (KD) function (Equation 1) are used to propose the SAP index.

2.2.1 The Urban centres catchment areas

Since this study aims to assess accessibility in rural areas, where there are major gaps in the transport network mapping (Benevenuto et al, 2018), instead of using a threshold travel time like other traditional methodologies (Song et al, 2018; Dai and Wang, 2011; Langford et al, 2006), it is applied thresholds of linear distances to keep consistency among regions despite the level of accuracy of mapped transport network of each region.

³ Gravity-based measures have been widely used since late 1940s. It is a location-based accessibility measure that estimate the potential accessibility of opportunities in a given zone to the surrounding other zones, in which smaller and farther opportunities provide diminishing influences (Geurs and van Wee, 2004).

The Kernel Density function⁴ (calculated by ArcGIS in this study) consists of a continuously gradual decay function within a threshold distance and no effect beyond (Wang, 2012). The specific formula used in this study by means of ArcGIS 10.5 (Equation 1) is based on the quartic kernel function described in Silverman (1986). In this model this implies that i) the higher the hierarchy of the urban centre, the wider the threshold distance, and ii) the closer the rural cell is to the urban centre, the higher is the urban influence score over it. To avoid a border/edge problem, urban centres from the surrounding areas of the study case region have also been included, as shown in Figure 1.

$$K_j(x) = \begin{cases} w_i \cdot \frac{3}{\pi} \cdot (1 - x_j^T \cdot x_j)^2 & \text{if } x_j^T x_j < 1 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where:

K_j is the influence score generated by urban centre i attributed to the location j

x_j is the distance between the urban centre i to the location j

w_i is the weight of urban centre i varying from 1 (for Local Centres) to 5 (for Metropolis)

References for FCA can be mostly found in the literature addressing health care accessibility (Neutens, 2015; Luo and Qi, 2008; and Yang et al, 2005), as well as access to employment, leisure and public transport services (Langford et al. 2012). These studies often apply thresholds driving time for estimating FCA to specific services, for example 30 minutes for primary care and urgent health services, 45 minutes for obstetrical services or radiotherapy, and 90 minutes for general surgeries. (Polzin et al, 2014; Fortney et al, 2000; Hughes et al, 1981).

In the Brazilian context, population arrangements and regional divisions have been developed to describe how the urban fabric is connected into regional networks of municipalities (IBGE,

⁴ The Kernel methods refer to the nonparametric density estimation that was originated as a numeric approximation to the derivative of the cumulative distribution function presented (Scott, 2015).

2016; and IBGE, 2017). Still, since there is not a precise threshold distance of the urban influence over the surrounding rural settlements, this research proposes here three sets of threshold distances in a sensitivity analysis of the SAP index following similar methodologies already applied by other authors (Pereira, 2018; Luo and Wang, 2003).

The first set of results presented at Table 1 is based on the findings of Benevenuto et al (2018) which present the average distances from nearly half million extreme poor households to the closest urban centres in Rural Northeast Brazil. The second threshold set is a referral obtained in semi-structured interviews with planning specialists and practitioners from the Superintendency for the Development of the Northeast (SUDENE). Finally, the third one is composed of the rounded average distance from the centroid of each rural cell (a point at the centre of each rural square of 1x1km) in Northeast Brazil to the closest urban centre of each centrality level, which was calculated for this study by means of GIS tools.

Table 1: Catchment areas by each urban centrality level

Centrality level	Threshold distance 1	Threshold distance 2	Threshold distance 3
Metropolis	320 km	100 km	340 km
Regional Centre	125 km	80 km	125 km
Sub-regional Centre	70 km	60 km	85 km
Zone Centre	40 km	40 km	45 km
Local Centre	10 km	20 km	15 km

2.2.2 The Floating Catchment Area model applied to calculate urban influence scores

Typically, in the first step of a 2SFCA model, the total population under the catchment area of a given POI is computed to calculate the ratio POI-to-population in a given area. This is basically a ratio between the supply and demand to account for the competition of the population sharing the same POI (Wang, 2012). In the second step, the ratios of the POI's

located within the threshold distance from each population location (e.g. a population grid cell, a neighborhood, a census tract, etc) are summed up to create an accessibility index for each population location.

However, since the POI in this case study is an aggregated proxy (i.e. an Urban Centre) for several other POIs, this ratio could mislead the proposed model to underestimate the availability of opportunities (POIs) in highly populated urban centres. Since the centrality level of each urban centre is also dependent on the number of its inhabitants, urban centres with large populations would, as a rule, represent a higher number of POI's, rather than only higher competition for them (or less availability of POI's).

Therefore, the 2SFCA method is adapted in the model in this paper, creating an influence area (like a FCA) that follows a KD decay function (Equation 1) and considers also the hierarchy level of each urban centre (Table 1). Finally, the summation of these influence areas is attributed to each rural cell of the case study region. Figure 2 presents the implementation of this process by using with GIS tools.

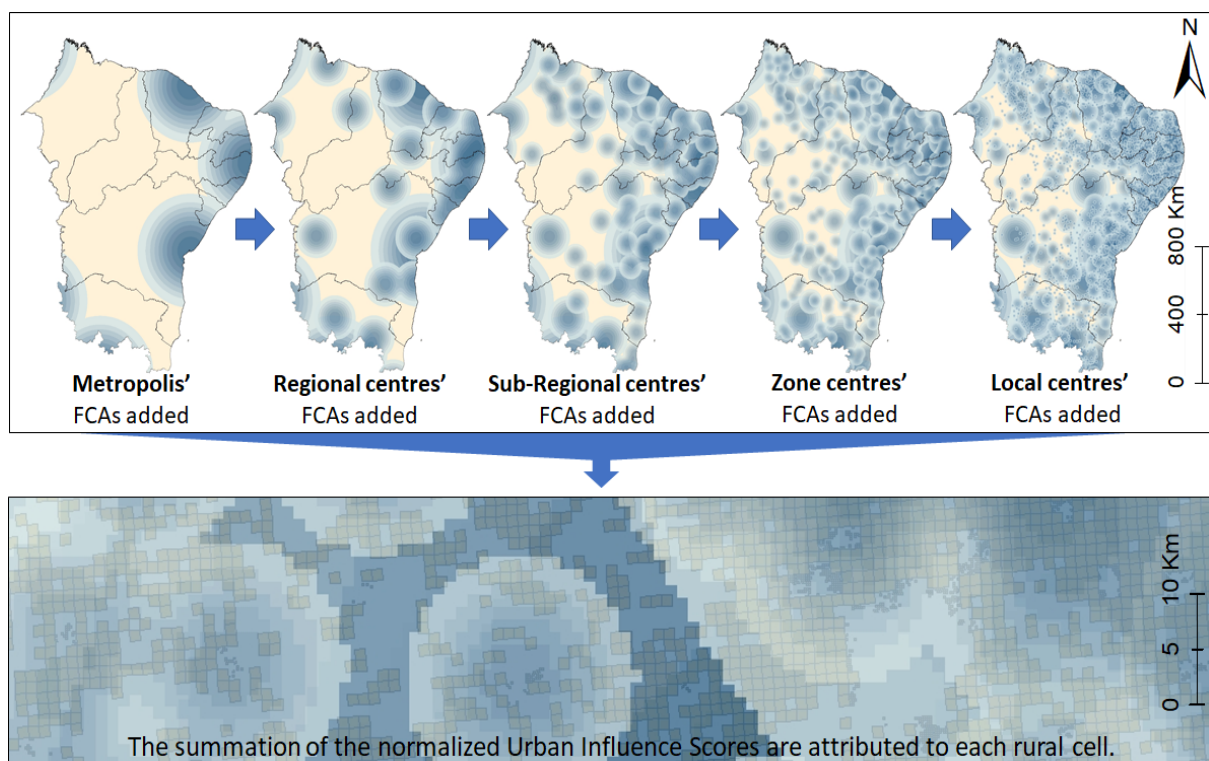


Figure 2: Calculation process of the urban influence scores over the rural cells (1x1km)

2.2.3 The Spatial Accessibility Poverty (SAP) index at a municipality level

In order to implement a SAP indicator at a municipality level that can serve as an aid for prioritisation processes of transport interventions, an aggregation of the rural cells is proposed which conjugates two factors: intensity (how spatially excluded is the population from the basic facilities?) and the extent factor (how many people are being affected by such spatial accessibility poverty?).

This approach has been firstly applied to assess the size and scope of accessibility poverty by Martens and Bastiaanssen (2014). The authors have based their methodology in the Sufficiency principle, which stresses that transport policies should first address the accessibility needs of people who fall below a minimum level of accessibility (Martens and Bastiaanssen, 2014). Despite the very objective propositions and insightful discussions on this topic, the question of how to define an absolute accessibility poverty line (similarly to the absolute income poverty line) remains open.

In that sense, the present model builds on the Prioritarianism principle to propose the municipality SAP indicator. This approach is based on a distributive rule that suggests a higher value of a gain when it is offered to the people in the worst-off position (Martens et al 2015, Pereira et al, 2017). By doing so, an innovative and simple measure of spatial accessibility poverty is then established to shed light on regions that require a higher priority of transport interventions.

Hence, the Intensity factor of the proposed model is composed of the normalized difference between the maximum urban influence score of the entire region (Y_{max}) and the urban influence score of each rural cell (j). The Extent factor is represented by the number of people

living in each rural cell. Finally, the SAP index is a summation of the intensity factor weighted by the extent factor of all rural cells within a municipality as described in Equation 2:

$$SAP_j = \frac{1}{N_j} \sum_{i=0}^{q_j} n_i \cdot \left(\frac{Y_{max} - Y_i}{Y_{max}} \right) \quad (2)$$

Where:

- Y_i the urban influence score over a rural cell i
- Y_{max} the maximum influence score of the entire case study region.
- n_i the population of the rural cell i
- q_j the number of rural cells in the municipality j
- N_j the total population of the municipality j
- SAP_j the Spatial Accessibility Poverty index of the municipality j

The well-known modifiable areal unit problem (MAUP) (Openshaw, 1984) could arise into the model when aggregating the influence scores to create the SAP index to each municipality. Though, according to some authors (Dark and Bram, 2007; Hay et al, 2001), a weighting function might reduce the effect of the MAUP when aggregating spatial data by incorporating object-specific measures throughout the analysis of the upscaled data. Therefore, since the SAP index is based on an aggregation of several⁵ small cells (1x1km) per municipality, which are weighted by the ratio of the population located on each cell, the MAUP bias tends to be reduced. Moreover, the SAP index is intended to provide an aid for transport planning that could support evidenced-based decisions (e.g. resources allocation) at the municipality level or at a higher scale, making this issue even less observable in the presented results. Nevertheless, further applications of the SAP index should be done carefully.

2.3. Municipalities' profile analysis

⁵ There are nearly 600 rural cells in each municipality one on average in sample considered to this case study.

An additional factor analysis is proposed to further investigate the interactions of the SAP index with potential socio-economic patterns of the municipalities experiencing higher levels of accessibility poverty. For this purpose, the average of the three estimated SAP indices is considered to compare the municipalities' profiles. The comparisons are made between the 80% lowest SAP scores (i.e. 1592 municipalities) vis-à-vis the 20% highest SAP scores (i.e. 398 municipalities). The descriptive statistics summary of twenty socio-economic and demographic indicators is then evaluated at this step. These indicators are taken from the latest Brazilian Census (IBGE, 2010) and the list, although not exhaustive, can provide a fair overview of basic dimensions required for the human flourishing in a rural environment.

Hence, it is possible to appreciate the vector of selected indicators from the perspective of five general domains of capabilities deprivations⁶. The dimensions listed below have been selected for convenience based on the existing census data that are available for all municipalities and are disaggregated by location (rural/urban):

1. Freedom of Movement (SAP, road density, car and motorbike ownership)
2. Housing Facilities (toilet, electricity, sewage disposal⁷)
3. Education (illiteracy rates⁸ and availability of rural schools)
4. Health (availability of rural healthcare centres and hospitals⁹)

⁶ For further reflections on this, see Sabina Alkire (2007) 'Choosing Dimensions: The Capability Approach and Multidimensional Poverty'.

⁷ An adequate sewage disposal has been considered when the household has access to either the general sewage network or a septic tank.

⁸ The rates for illiteracy consider the percentage of people of 10 years of age or more who are illiterate.

⁹ The only information health-related that is available from the census (IBGE, 2010) for all municipalities that is also disaggregated by location (urban/rural) are the numbers of population with any mental, visual, motor or hearing impairment. Therefore, only the number of health care centres has been considered in the Health domain.

5. Wealth (income-poverty levels)

Beyond these four dimensions, the descriptive statistics of other municipality-wise characteristics are included, such as GDP, population size and density, and share of the rural population. Moreover, since there is no data available of the income-poverty levels by municipality that are also disaggregated by location (rural/urban) for the entire region, for the Wealth domain it was considered three poverty lines dependent on the per capita income (PCI) of rural families:

- Extreme Poverty when $PCI < 1/4$ of the minimum wage¹⁰
- Poverty when PCI is between $1/4$ and $1/2$ of the minimum wage
- Vulnerable to poverty when PCI is between $1/2$ and 1 of the minimum wage

3. Results and Discussion

3.1 Sensitivity analysis

The sensitivity analysis of the SAP index has shown that at the state-wise level the different threshold distances used to estimate the urban influence have not presented an intense impact upon the estimated accessibility poverty. Figure 3 presents the three different SAP indices plotted at the same color scale to allow a visual comparison of the spatial patterns.

As it can be expected, mostly regions along the shore (right and upper parts of the map), which have a higher concentration of urban centres (see Figure 2), have presented lower levels of spatial accessibility poverty in the three trials. The two larger spots in blue colour that are common in the three maps represent the metropolitan area of Salvador (Bahia's state capital) and the conurbation of the metropolitan regions of Recife (Pernambuco's state capital) and

¹⁰ The minimum wage in 2010 was R\$ 510.00 a month – around U\$ 368.00 in 2010 purchasing power parity according to the conversion rate provided by OECD (2018)

João Pessoa (Paraíba's state capital). In contrast, the inner mainland areas are clearly the most affected by accessibility poverty in both cases, with an overall remarkable low accessibility presented in Maranhão and Piauí states (the two at the top left side of the map).

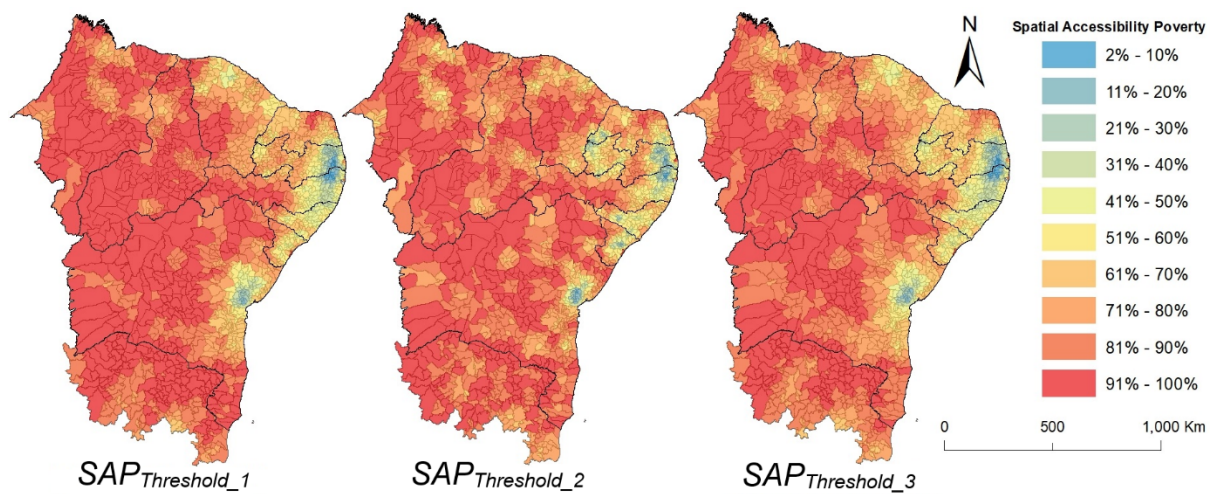


Figure 3: Spatial Accessibility Poverty by different thresholds of Urban Influence

On the other hand, in closer look, it is possible to notice that the different threshold distances have resulted in variations of the SAP index ranking of municipalities. For instance, one in every five municipalities top-ranked in the 20% highest $SAP_{Threshold_1}$ would not be top-ranked if either $SAP_{Threshold_2}$ or $SAP_{Threshold_3}$ were used instead. The difference between threshold 2 and 3 has had a smaller scale, but still, one in every ten municipalities top-ranked using $SAP_{Threshold_2}$ would not be top-ranked if $SAP_{Threshold_3}$ was used instead, and vice-versa.

Even though any reasonable threshold distance may promote a more evidence-based decision making, in terms of prioritisation of transport interventions, the findings from the presented sensitivity analysis suggest that such SAP scores should not be taken in separately from each other. Especially when appraising transport interventions at a smaller scale, where there is a higher fluctuation of scores, it is important to remark that local authorities should consider sensitivity analysis to evaluate the variation and distributional effects of a range of distances and/or time cut-offs of the accessibility indices.

3.2. Factor analysis

The results of the factor analysis show much more than just explain the differences between municipalities with higher and lower accessibility levels, are intended to evaluate whether the newly defined SAP index generates reasonable results. A summary of such descriptive statistics is presented in Table 2. However, since other capabilities domains (Alkire, 2007) and much relevant spatial information could not be included in the present analysis (mostly due to the lack of data), prescriptions of transport interventions to tackle accessibility poverty should be done carefully.

It is clear from the findings presented in Table 2 that municipalities with higher spatial accessibility, despite having similar shares of rural population to the others, they are usually higher in population and nearly twice smaller in area, which obviously leads to an intense concentration of rural settlements. Moreover, the municipalities better ranked by the SAP index presented approximately twice more GDP when compared to the others, which indicates less economic activity, fewer job opportunities and, considering a do-nothing scenario, less budget to be invested in the municipality.

Under the Freedom of Movement domain, Table 2 depicts that while road density is nearly 60% higher in municipalities with better spatial accessibility, car and motorbike ownership rates in rural areas are virtually the same for both groups. The difference in road density could be explained again by the larger average areas of municipalities in accessibility poverty. Under these circumstances, the similar car ownership rates suggest less ease of movement in the municipalities larger in area, since road passenger transport is mostly the only available option¹¹ in rural northeast Brazil, and longer distances would inevitably exclude even more people without a motorised transport.

¹¹ With the exception of communities along the Parnaíba and São Francisco basins, as well as by

Table 2: Factor analysis of the municipalities with higher SAP index

Variable	Municipality accessibility	Unit	Mean	Std. Dev (\pm)	Min	Max
SAP index (average)	High	%	65%	19%	5%	91%
	Low		95%	2%	91%	100%
Area	High	km ²	636	916	20	15,157
	Low		1,949	2,087	167	16,304
Gross Domestic Product	High	R\$ 1000	467,007	2,505,042	11,439	57,872,793
	Low		256,766	1,329,454	16,649	20,904,276
Total Population	High	-	26,418	95,514	1,102	2,355,817
	Low		18,002	44,564	1,911	709,365
Population density	High	Inhab/km ²	79	331	1	7,969
	Low		29	254	1	4,241
Share of population in rural areas	High	%	44%	19%	1%	92%
	Low		50%	18%	2%	87%
Road density	High	km/100km ²	2.7	4.0	0.0	43.8
	Low		1.7	2.3	0.0	23.7
Car ownership in rural areas	High	%	10%	6%	0%	41%
	Low		9%	6%	0%	29%
Motorbike ownership in rural areas	High	%	32%	15%	2%	73%
	Low		33%	13%	3%	75%
Rural Hospitals	High	-	0.1	0.3	0.0	2.0
	Low		0.1	0.3	0.0	1.0
Rural Basic healthcare units	High	-	1.7	2.2	0.0	17.0
	Low		2.7	2.8	0.0	18.0
Rural Primary Schools	High	-	15.7	15.5	0.0	139.0
	Low		21.2	25.4	0.0	173.0
Rural High schools	High	-	0.4	1.1	0.0	20.0
	Low		0.9	1.9	0.0	20.0
Illiteracy in Rural population +10 of age	High	%	30%	6%	5%	67%
	Low		29%	6%	12%	46%
Rural households with no electricity	High	%	3%	5%	0%	53%
	Low		8%	9%	0%	54%
Rural households with no toilet	High	%	11%	10%	0%	65%
	Low		19%	13%	0%	62%
Rural households with no adequate sewage disposal	High	%	38%	18%	0%	89%
	Low		45%	16%	2%	84%
%Rural families in extreme poverty	High	%	36%	15%	2%	100%
	Low		37%	14%	5%	100%
%Rural families in poverty	High	%	20%	12%	0%	100%
	Low		17%	10%	0%	68%
%Rural families vulnerable to Poverty	High	%	12%	9%	1%	100%
	Low		12%	8%	1%	47%

The results show that, from the perspective of access to education, the number of rural schools (primary and high) are steadily higher in municipalities experiencing greater accessibility poverty, even though their rural population is lower than the other group of municipalities. Since the rural illiteracy rates are about the same (approximately 30%), these findings suggest that a less centralised allocation of schools may have compensated the accessibility poverty

Carajás Railroad.

impacts on education. Further investigations considering also the number of rural school buses per municipality could bring more insights to the agenda of transport interventions that are more likely to be effective in tackling deprivations of this domain.

In the Health dimension, while the number of Basic health care units are 58% higher in municipalities with lower spatial accessibility, the number of Hospitals is at the same average for both groups. This highlights the need for longer trips to reach medical services of higher complexity in rural settlements affected by spatial accessibility poverty, as presumed in the initial assumptions.

The findings on the essential housing facilities show that people accessibility deprived also experience less access to electricity and sanitation facilities (toilet and appropriate sewerage system). Moreover, Table 3 points out that these three indicators of housing facilities are also statistically correlated to that the SAP index (by Spearman's correlation). Two dispersion graphs of the SAP index vis-à-vis access to Electricity and Toilets are presented in Figure 4.

As already highlighted by Vakis et al (2016), the access to these basic services appears to be as the main driver out of chronic poverty in countries from LAC. Since these indicators and the SAP index tend to be geographically concentrated, it can be argued that the SAP index can also add value to the discussion of how transport development can contribute to the reduction of the intergenerational poverty.

Table 3: Statistic correlation by Spearman's method between SAP index and other indicators

Variable	Correlation Coefficient
Area	.270**
Gross Domestic Product	-0.014
Total Population	-0.051
Population density	-.339**
Share of population in rural areas	.172**
Road density	-0.061
Car ownership in rural areas	0.013

Motorbike ownership in rural areas	0.055
Rural Hospitals	0.008
Rural Basic healthcare units	0.042
Rural Primary Schools	0.069
Rural High schools	-0.012
Illiteracy in Rural population +10 of age	-0.096
Rural households with no electricity	.239**
Rural households with no toilet	.166**
Rural households with no adequate sewage disposal	.217**
%Rural families in extreme poverty	0.023
%Rural families in poverty	-.105*
%Rural families vulnerable to Poverty	-.119*

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level (2-tailed)

Finally, the results presented in Table 2 indicate that for the Wealth domain, there is not a significant variation of the average rates at any income-poverty level, despite two of them being statistically correlated to the SAP index as shown in Table 3. This similarity of figures once again calls the attention that poverty is composed of deprivations that cannot be captured by income indicators alone. In that sense, it is safe to say that to sustain an inclusive development of transport services and infrastructure in the rural Global South, a dimension of spatial accessibility poverty must be included as a critical factor for its planning and decision-making process.

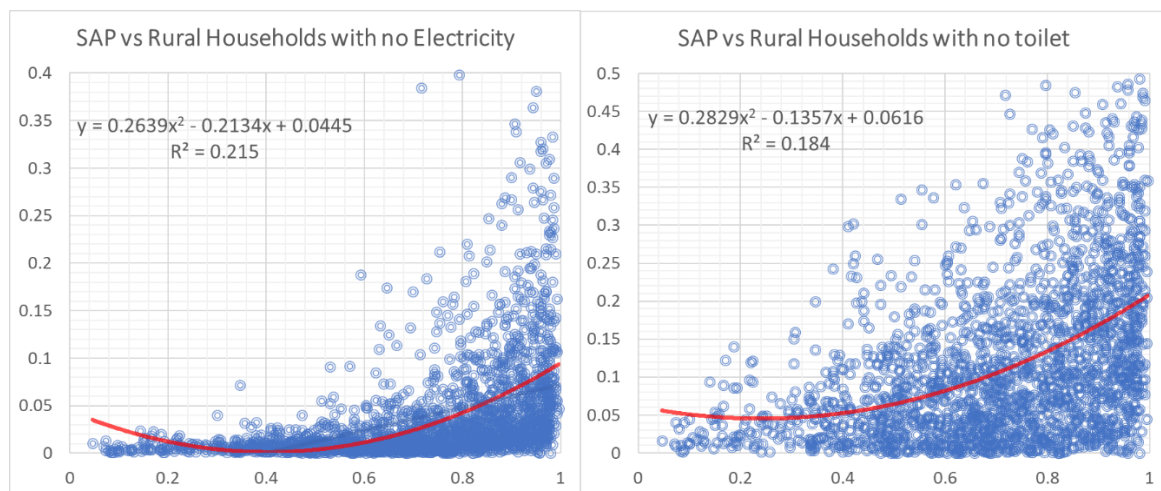


Figure 4: Spatial Accessibility Poverty vs Basic Housing facilities

4. Conclusion

This study has presented an innovative index to estimate the overall access to basic services in rural areas. The presented findings shed light particularly on municipalities of the Northeast Brazil that are mostly affected by such spatial accessibility poverty. Yet, since the SAP index requires just a fairly basic spatial dataset to be processed, it is potentially replicable globally.

Considering the current gap of knowledge on this topic, the SAP index represents a substantial progress in the quantitative measurements of the spatial accessibility in rural areas of the Global South, where the majority of the poor still live (Iimi et al, 2016). This index has then a critical role to promote a new standard of transport development strongly committed in eradicating poverty.

The appreciation of such index is also intended to open the debate in the Transport Planning realm on where and for whom transport interventions ought to be mostly targeted to. Arguably, including indicators such as the SAP index in transport appraisal frameworks should provide means to consider the social impact and equity in a much less biased and paternalistic fashion.

When assessing the SAP index in the sensitivity analysis, the presented results show that even though the threshold distance size has led to up to 20% of variation in the list of the top-ranked municipalities, only minor variations have been found at a macro level. This fact, once again suggests the importance of considering such sensitivity analysis and complementary factor analysis when applying the SAP index for action prioritisation purposes.

Additionally, the factor analysis has presented five domains of capabilities deprivations that can be drawn from census indicators to investigate potential patterns of the municipalities most affected by accessibility poverty. Perhaps, contrary to the expectations, the findings point out that the share of rural population is not a determinant factor to spatial accessibility poverty. Instead, other factors like deprivation of housing facilities and low population density appear to be strongly associated to critical SAP levels.

For future studies, the disaggregation of the SAP index for each service and opportunity (education, health, jobs, etc) should be done as soon as the location of the services become available. More accurate results will be also possible when the census indicators for the rural areas become disaggregated in smaller areas (by census tract, or neighbourhood for example). Meanwhile, the proposition of new transport interventions targeting poverty reduction should consider accessibility poverty indicators, like the SAP index, in addition to other socio-economic and transport-related indicators that could depict the specific needs and particularities of each region.

Finally, it is argued that poverty reduction policies are more likely to be effective in the long run if they also address the accessibility dimension of poverty in a systematic way as discussed throughout this study. Since access to services and opportunities is a key difference between those who has escaped chronic poverty those still trapped in it (Vakis et al, 2016), the SAP index and other indicators of transport-related exclusion are crucial to promote a new standard of transport development strongly committed in eradicating poverty.

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