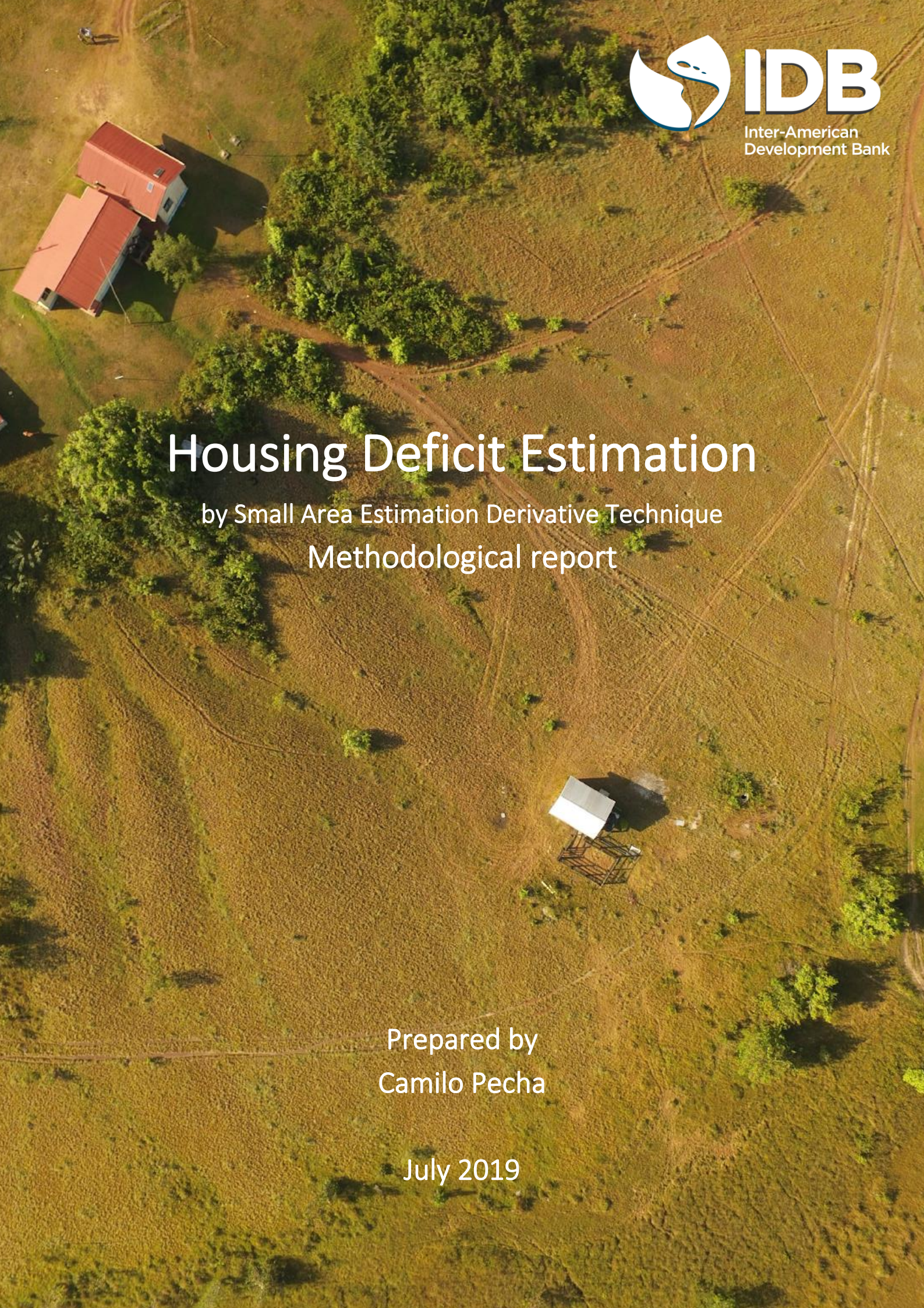

IDB
Inter-American Development Bank

Housing Deficit Estimation

by Small Area Estimation Derivative Technique

Methodological report

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July 2019

Acknowledgment

This report is presented as second deliverable for the consultancy on Housing and Urban Development Small Area Estimation. I want to thank to Jordan Jasuta Fischer and Patricio Zambrano-Barragán for their support.

TABLE OF CONTENTS

I. INTRODUCTION

Guyana is home to close to 750,000 people, of which more than 90% lives on a semi-continuous urban coastal strip that represents only 5% of total land area. The country is divided into 10 regions, each composed of local Neighborhood Democratic Councils—the smallest local-level administrative unit. On the coastal strip, Region 4 alone, which includes the capital and primary city of Georgetown and its low-density peri-urban areas, contains over 40% of the country's population. The urban coastal region and the rural hinterland each present unique challenges for housing policy.

The Government of Guyana (GoG), through the Central Planning and Housing Authority (CHPA), is committed to the long-standing goals of expanding the supply of housing, improving affordability, and ensuring access to housing and infrastructure for poor households—and doing so in the context of the development of sustainable and resilient communities. Over the last five years, HUD has worked closely with CHPA on this mission, primarily through loan operations and technical assistance. As part of HUD's support for the development of a National Housing Strategy, CHPA requested support for improved data gathering, management, and analysis, in support of improved and transparent policy design and implementation. Over the last year, HUD has focused on improving the agency's integrated territorial/geospatial data management system, through the collection and clean-up of a variety of GIS[1] datasets.

However, the agency still lacks a comprehensive understanding of housing deficits in the country. To date, HUD and CHPA have based their program design primarily on 1) ad hoc relevant information extracted from the 2012 census and 2) internal data about housing demand from CHPA, which is gathered through their applications and associated waiting lists for households interested in the agency's programs.

This scattered data on housing conditions suggest that Guyana faces primarily quantitative housing deficits. In addition, Guyana is one of a few developing countries that saw a decline in its population in the 2002-2012 inter-census period—though the recent discovery of vast offshore oil reserves may alter this pattern and affect future housing demand and overall land markets. Given this information, to date, HUD and CHPA believe the current approach is effective, but still require more granular and more up to date information to better carry out program and policy design. Thus, the strengthening of data management and analysis capabilities will enable national and local stakeholders in Guyana to minimize operational mistakes, adverse strategic decisions or economic loss for the successful development of a National Housing Strategy.

[1] Geographic Information System

This document will present a methodology to estimate qualitative and quantitative housing deficits at the most granular level existing data allows. In the first section, a definition of quantitative and qualitative deficits is presented, followed by a discussion of the data required to adequately build the numeric indices, based on proven methodologies like the one employed by Colombia's DANE[2]. In the next section, deficits are calculated, and finally, the last section will explain the methodology to predict deficit for different periods using nighttime lights data from satellite imagery.

II. DEFINITIONS

In this section, some important definitions will be presented based on international literature on housing deficit. Sources of information like the UN HABITAT and DANE will give important insights in terms of definitions and how to measure those issues.

Quantitative housing deficit.

MINURVI[3] has defined quantitative housing deficit as "…the amount of new housing that is needed so that all households that need housing have a decent space that allows them to develop their reproductive, family and social activities."[4] With this, a basic indicator for quantitative deficit will refer to the difference between the total number of households and the number of occupied housing units.

Qualitative housing deficit.

On the other hand, MINURVI has defined qualitative housing deficit as: "…dwellings that have deficiencies in the structure of the floor, space, availability of public services and, therefore, [require the provision of] public services, improvement or expansion of the housing unit"[5]
More specifically, ECLAC[6] has defined three aspects to take into consideration to measure qualitative deficit: 1. Materials of walls, roof, and floor, 2. Overcrowding (number of people per room at home), and 3. Access to utilities (potable water, sewerage, and electricity)[7].

[2] Departamento Administrativo Nacional de Estadística.
[3] General Assembly of Ministers and High Authorities of Housing and Urban Development of Latin America and the Caribbean
[4] MINURVI cited by UN HABITAT (2015)
[5] MINURVI cited by UN HABITAT (2015)
[6] Economic Commission for Latin America and the Caribbean
[7] ECLAC cited by UN HABITAT (2015)

III. HOW TO MEASURE HOUSING DEFICIT

This section will describe the data required to calculate quantitative and qualitative housing deficit indicators. This section will be based on the exercise done by Colombia's Departamento Administrativo Nacional de Estadística (DANE, the National Statistics Office) on housing shortage[8], and the availability of microdata from Guyana's 2012 Census.

Total housing deficit is constructed based on total dwelling needs in terms of quality and quantity. To calculate this, it is important to determine the number of households living in suboptimal conditions in terms of building quality and overcrowding. Based on Guyana's Census data, a series of indicators were chosen to best represent housing deficit based on the information available, with certain categories considered 'inadequate', i.e., indicating a household in housing deficit.

The categories considered adequate or inadequate will vary in different climatological and cultural contexts. For example, indigenous communities may use traditional building materials for primarily cultural reasons; a colder climate will necessitate more insular building materials than a warmer one; and cultural considerations of 'crowding' vs. 'overcrowding' may change over decades and across regions. It is therefore imperative that this methodology be reviewed carefully and modified according to specific contexts and available information before any replication.

Guyana's housing deficit was calculated using the following indicators, which provide valuable insight into households' shelter needs. A table detailing variables, categories, and values assigned to create the housing deficit indices can be found in the Annex.

Wall material quality: The Census questionnaire includes the variable 'Main wall material' wherein materials like "Makeshift", "Galvanized", "Troolie palm" are considered inadequate.

Cohabitation: The Census also identifies cases of cohabitation, defined as two or more households sharing the same dwelling.

Overcrowding: This indicator is determined by the number of habitants per room. Where it is possible to differentiate between urban and rural households, it may be pertinent to apply different rules regarding overcrowding in urban and rural settings. In the case of Guyana, the census data does not include any indicator articulating this distinction, and thus more than 3 persons per room is considered overcrowding across the country.

[8] DANE 2009

Acute overcrowding: More than 5 people per bedroom is considered acute overcrowding for all parts of the country.

Roof material quality: The Census variable 'Main roofing material' indicates insufficient quality by materials like "Makeshift", "Sheet metal", "Troolie palm", and others.

Availability of utilities: The Census contains information regarding households' main source of lighting (where not having access to electricity is considered deficit), water (deficit will be defined by absence of piped water and access to water from spring/river/pond), sewerage (deficit is defined by not having WC connected to a sewerage), and garbage disposal (dumping on land, burning, dumping/throwing into river/sea/pond is considered to be deficit).[9]

Estimation process.

Housing deficit is treated as a binary variable for this estimation – a household is either in deficit (indicators aggregate to a number greater than zero) or it is not (indicators aggregate to zero). Once the deficit situation for each household has been defined, the scores of all indicators can be aggregated as follows in order to determine the size of quantitative, qualitative, and total housing deficits.

To estimate the **Quantitative Deficit**, two characteristics are aggregated:

1. Cohabitation: more than one household per dwelling,
2. Acute overcrowding: more than 5 people per bedrooms.

While they were not deemed necessary in the case of Guyana, should a stricter definition of quantitative housing deficit be preferred, two additional variables can be added to this calculation:

3. Inadequate dwelling: The census questionnaire uses the variable 'Type of building' to identify the type of construction in which a dwelling is located. Households living in buildings type "Other" or "Community Service" are identified as not residential, and therefore qualitatively deficient.
4. Inadequate unit: The variable 'Type of dwelling unit', where the categories "barracks", "makeshift", and "other" are identify households in deficit, is used to provide additional insight into the adequacy or inadequacy of dwelling types.

To estimate **Qualitative Deficit**, seven characteristics are aggregated:

1. Dwellings with low quality wall materials,
2. House with low quality roofing material
3. Overcrowding: three to four people per room for urban areas, and for rural more than three people.

[9] In particular, since there is no way to identify rural/urban areas from census data, it was important to incorporate potential indication of deficits for water access using an aggregation of urban indicator (lack of access to piped water) and rural indicator (main access to water from spring/river/pond).

4. Access to utilities:
    a. piped water,
    b. sewerage,
    c. electricity,
    d. garbage disposal

The estimation of **Total Housing Deficit** is calculated by summing up the quantitative and qualitative deficit. The share of population in housing deficit is equal to the number of households in deficit divided by the total number of households in the country. The following table will summarize the indicators at the national level and per region. For the NDC level, the indicators will be estimated per geographical location and shown in a map.

Table 1. Housing deficit nationally and by region

Characteristics	National (%)	Regions (%)									
		1	2	3	4	5	6	7	8	9	10
Total households	191730	4610	11416	28968	82192	13013	30195	3987	2226	4566	10557
Households without deficit	**13.42%**	**0.20%**	**3.07%**	**25.48%**	**46.49%**	**4.99%**	**15.69%**	**12.67%**	**2.20%**	**1.80%**	**21.60%**
Households in deficit	**86.58%**	**99.80%**	**96.93%**	**74.52%**	**53.51%**	**95.01%**	**84.31%**	**87.33%**	**97.80%**	**98.20%**	**78.40%**
Households in qualitative deficit	**86.09%**	**99.80%**	**96.86%**	**73.77%**	**51.08%**	**94.84%**	**83.90%**	**86.86%**	**97.66%**	**98.12%**	**78.01%**
Walls material	7.89%	**4.08%**	**0.21%**	**0.83%**	**0.24%**	**0.48%**	**0.19%**	**4.56%**	**23.27%**	**43.78%**	**1.24%**
Roofing material	13.16%	**31.04%**	**3.47%**	**0.13%**	**0.17%**	**0.18%**	**0.15%**	**6.90%**	**29.74%**	**58.96%**	**0.82%**
Overcrowding	9.60%	**23.90%**	**2.86%**	**1.06%**	**1.05%**	**1.03%**	**0.63%**	**9.15%**	**33.02%**	**22.14%**	**1.15%**
Piped water	46.95%	**80.67%**	**82.49%**	**36.79%**	**15.93%**	**11.98%**	**7.17%**	**67.80%**	**84.01%**	**53.57%**	**29.09%**
Sewerage	56.64%	**93.58%**	**48.97%**	**32.81%**	**23.14%**	**46.88%**	**45.05%**	**56.66%**	**92.77%**	**89.01%**	**37.52%**
Electricity	16.63%	**18.16%**	**14.48%**	**10.44%**	**7.83%**	**18.67%**	**13.08%**	**12.11%**	**50.27%**	**13.99%**	**7.29%**
Garbage collection	71.27%	**77.61%**	**86.24%**	**57.44%**	**36.40%**	**91.54%**	**76.03%**	**67.04%**	**65.63%**	**88.66%**	**66.11%**
Combination of qualitative issues											
Roofing and walls material	6.25%	3.71%	0.03%	0.03%	0.05%	0.08%	0.04%	3.54%	15.23%	39.62%	0.19%
Roofing material and overcrowding	7.90%	20.72%	1.84%	0.03%	0.02%	0.08%	0.05%	3.86%	19.23%	32.90%	0.30%
Roofing material and utilities	2.37%	5.55%	0.63%	0.08%	0.04%	0.05%	0.02%	1.13%	12.04%	3.88%	0.32%
Walls materials and utilities	1.45%	1.97%	0.11%	0.25%	0.08%	0.15%	0.01%	0.98%	8.27%	2.56%	0.16%
Overcrowding and walls materials	4.59%	2.32%	0.02%	0.28%	0.05%	0.14%	0.04%	2.48%	16.67%	23.81%	0.14%
Overcrowding and utilities	3.39%	6.46%	3.09%	1.05%	0.53%	0.95%	0.29%	3.19%	15.14%	2.12%	1.10%
Walls and roofing material , overcrowding, and utilities	0.68%	0.95%	0.00%	0.00%	0.01%	0.02%	0.00%	0.33%	4.58%	0.92%	0.03%
Households in quantitative deficit	**11.92%**	**28.57%**	**5.98%**	**4.70%**	**5.97%**	**5.14%**	**3.52%**	**12.37%**	**26.64%**	**22.47%**	**3.87%**
Cohabitation	2.17%	1.69%	1.95%	3.32%	4.42%	3.04%	2.27%	1.86%	0.54%	0.90%	1.69%
Acute overcrowding	9.87%	27.42%	4.18%	1.42%	1.64%	2.14%	1.29%	10.58%	26.10%	21.66%	2.23%
Type of building/dwelling	1.71%	5.16%	0.40%	0.62%	0.89%	0.38%	0.53%	3.09%	3.32%	1.99%	0.67%

Source: Original construction based on DANE (2009) and own calculations based on Guyana's 2012 census data.

Table 1 presents the housing deficit disaggregated by components and regions using data from Guyana's 2012 census. Based on the definitions made in this section, it appears that the most pressing issue in the country is qualitative deficit, which accounts for 86.04% of the population. The region with the largest deficit is Region 1 where almost every household is living in qualitative housing deficit and almost a third is living in quantitative housing deficit. On the other hand, the best performer is Region 4 with about half the population living in qualitative deficit and less than 6% are living in quantitative deficit. When disaggregated, the largest contributor to qualitative deficit is access to sewerage, followed by access to water. For quantitative deficit, the highest contributor is acute overcrowding.

In order to determine the statistical accuracy of the indicators, a coefficient of variation (CV) is calculated. The CV will capture the indicators' dispersion so that the researcher can define how informative the indicator is in statistical terms. The CV is defined as the standard deviation of the indicator divided by indicator's mean multiplied by 100. The lower the CV, the more precise the estimation is. DANE, in Colombia, has defined a scale to determine how informative or precise a housing indicator is:

Table 2. Definition of accuracy of indicators based on CV value.

Qualification	Value of coefficient of variation
Good	CV<7.5
Acceptable	7.5≤CV<15
Low precision	15≤CV<30
Bad	30≤CV

Source: Original construction based on DANE (2009)

The following table presents the value of coefficient of variation for those figures estimated in table 1. As can be seen, the most accurate indicators correspond to the most pressing issue and its more representative components: Qualitative-> Sewerage and piped water. The less precise indicators are those identifying combination of issues, wall and roof materials, and type of dwelling. One important observation is that the indicator for qualitative deficit is more precise (and therefore with higher statistical accuracy) than the quantitative deficit one.

Table 3. Coefficient of variations for housing deficit in Guyana.

Characteristics	National (%)	Regions (%)									
		1	2	3	4	5	6	7	8	9	10
Total households	191730	4610	11416	28968	82192	13013	30195	3987	2226	4566	10557
Households without deficit	**1.13**	**22.61**	**5.61**	**1.71**	**1.07**	**4.36**	**2.32**	**2.63**	**6.67**	**7.35**	**1.88**
Households in deficit	**0.75**	**0.04**	**0.18**	**0.58**	**0.93**	**0.23**	**0.43**	**0.38**	**0.15**	**0.14**	**0.53**
Households in qualitative deficit	**0.76**	**0.04**	**0.18**	**0.60**	**0.98**	**0.23**	**0.44**	**0.39**	**0.15**	**0.14**	**0.54**
Walls material	0.74	5.19	22.26	11.67	22.93	15.08	28.55	6.02	1.83	1.93	11.17
Roofing material	0.97	1.50	5.29	30.55	34.50	26.15	35.46	4.14	1.55	0.89	12.24
Overcrowding	0.64	1.78	5.82	9.68	9.71	9.80	12.53	3.15	1.42	1.88	9.29
Piped water	0.75	0.49	0.46	1.31	2.30	2.71	3.60	0.69	0.44	0.93	1.56
Sewerage	0.55	0.26	1.02	1.43	1.82	1.06	1.10	0.87	0.28	0.35	1.29
Electricity	0.29	2.12	2.43	2.93	3.43	2.09	2.58	2.69	0.99	2.48	3.57
Garbage collection	0.46	0.54	0.40	0.86	1.32	0.30	0.56	0.70	0.72	0.36	0.72
Combination of qualitative issues											
Roofing and walls material	0.95	5.40	61.68	60.17	48.45	38.01	100.32	6.82	2.38	2.10	22.95
Roofing material and overcrowding	1.04	1.97	7.31	56.73	74.02	40.32	54.94	5.43	2.06	1.47	20.53
Roofing material and utilities	0.95	4.16	12.55	37.13	53.23	51.01	77.71	10.20	2.72	5.25	18.43
Walls materials and utilities	1.03	7.48	32.20	21.09	38.64	26.87	100.32	11.68	3.34	7.69	24.90
Overcrowding and walls materials	0.91	6.97	75.55	19.63	53.23	30.47	57.91	8.16	2.25	2.72	27.44
Overcrowding and utilities	0.56	3.80	5.60	9.71	13.69	10.20	18.39	5.51	2.37	6.79	9.49
Walls and roofing material , overcrowding, and utilities	1.21	10.56	0.00	170.20	143.34	114.07	0.00	19.94	4.59	13.48	59.32
Households in quantitative deficit	**0.40**	**1.58**	**3.96**	**4.50**	**3.97**	**4.30**	**5.23**	**2.66**	**1.66**	**1.86**	**4.98**
Cohabitation	0.35	7.62	7.09	5.40	4.65	5.64	6.57	7.27	13.59	10.51	7.64
Acute overcrowding	0.56	1.63	4.79	8.34	7.74	6.76	8.74	2.91	1.68	1.90	6.63
Type of bukding/dwelling	0.43	4.29	15.72	12.68	10.55	16.27	13.74	5.61	5.39	7.01	12.15

Source: Original construction based on DANE (2009) and own calculation based on Guyana's 2012 census

IV. INDICATORS' ESTIMATION BASED ON DECISION RULES

To estimate the indicators for housing deficits, a set of rules is defined. In particular, the following rules will help to identify the deficit condition of a household through some conditions related to the variables described above. The following are the rules designed to measure housing deficit.[10]

The rules for cohabitation and acute overcrowding are used to measure the size of quantitative deficit. In principle, a household will be in quantitative housing deficit if at least one of the following rules is satisfied:

$$Cohabitation = \begin{cases} 1 \; if \; household \; share \; dwelling \\ 0 \; otherwise \end{cases}$$

Meaning that, in the dataset, a household that shares its dwelling with other(s) household(s) will has a 1 and 0 otherwise.

$$Acute \; overcrowding = \begin{cases} 1 \; if \; more \; than \; 5 \; people \; per \; bedroom \\ 0 \; otherwise \end{cases}$$

Thus, taking the ratio between the household size and the number of bedrooms, a household which ration goes above 5 people per room will be assigned with 1 and 0 otherwise.

The size of the quantitative housing deficit in region *j* will be determined by the fraction of households that comply with any of the mentioned rules relative to the total number of households in region *j*:

$$QuantiHD_j = \frac{\sum_i (Cohabitation_{ij \; where=1} \; OR \; Acute \; overcrowding_{ij \; where=1})}{total \; households_j}$$

Where the numerator is defined by the sum of all of households *i* in region *j* that are in cohabitation or in acute overcrowding.[11] The denominator is the total number of households in region *j*.

[10] Table A1 in the annex presents all the variables used in the estimations, the corresponding categories, and values assigned in terms of deficit.

[11] In the case a household presents cohabitation AND acute overcrowding, the indicator will take a value of one for qualitative deficit.

As explained in the previous section, qualitative deficit is measure using quality of walls and roof materials, and access to public utilities. The rules to measure the size of qualitative housing deficit are the following.

$$Walls = \begin{cases} 1 \; if \; main \; material \; is \; "Makeshift", \; "Galvanized", \; "Troolie \; palm" \\ 0 \; otherwise \end{cases}$$

$$Roof = \begin{cases} 1 \; if \; main \; material \; is \; "Makeshift", \; "Sheet \; metal", \; "Troolie \; palm" \\ 0 \; otherwise \end{cases}$$

In terms of dwellings' structure, measures of the quality of construction materials will give an idea of dwellings' durability. In particular, Guyana's census incorporates questions regarding wall and roofing materials, however no information regarding floors is captured.[12] The rules are defined so that those households living in dwellings with non-durable materials are considered to be in housing deficit and therefore are valued as a 1 in the data, and 0 otherwise.

$$Overcrowding = \begin{cases} 1 \; if \; more \; than \; 3 \; people \; per \; room \\ 0 \; otherwise \end{cases}$$

With respect of the available space of a dwelling to develop social and biological activities, a less stringent measure of acute overcrowding is used and is defined by the ratio between the household size and the number of rooms.[13] If the ratio goes above 3 people per room, the household is consider to be in a situation of overcrowding and therefore it is assigned a 1 in the data, or 0 otherwise.

With respect to access to basic services, the availability of electricity, piped potable water, sewerage, and/or garbage collection help to determine if a dwelling has sufficiently habitable conditions.

$$Lighting = \begin{cases} 1 \; if \; no \; access \; to \; electricity \\ 0 \; otherwise \end{cases}$$

The most common way to identify the availability of electricity is through information related to main sources of lighting in the dwelling, collected by the census. A household is considered in deficit if it lacks access to electricity by private or public means, so it is assigned a 1 for lighting; those that have access to electricity are assigned a 0.[14]

[12] Internationally speaking, some methodologies incorporate the quality of outer walls materials as part of the indicators or rules for quantitative deficit calculations. If a weak dwellings' structure is considered to be important for quantifying the replacement need of units, the quality of walls' material should be considered as part of quantitative deficit. In the case of Guyana, due to the absence of information on floors' material, the quality of walls and floors were used as measures of housing material quality as recommended by CEDLAC (UN-HABITAT 2015)

[13] Note that this rule takes into consideration number of rooms *not including* bedrooms. In particular, Guyana's census gathers information on number of rooms other than bedrooms, and number of bedrooms separately. If it is not the case, the use of number of rooms for both acute and not acute overcrowding could be acceptable.

[14] Currently, Guyana's census incorporates information related to solar or inverter access to lighting which was considered as positive access to electricity.

$$Water = \begin{cases} 1 \; if \; no \; access \; to \; piped \; water \; and/or \; \; main \; acces \; is \; spring, \; river, \; or \; similar \\ 0 \; otherwise \end{cases}$$

Access to quality source of water is considered in deficit when dwelling has no access to piped water or when its primary water source is identified as spring, river, or similar; sources that would not warrant sufficient water quality for human consumption (DANE 2009).

$$Sewerage = \begin{cases} 1 \; if \; WC \; is \; not \; connected \; to \; sewerage \\ 0 \; otherwise \end{cases}$$

Adequate access to waste water management is considered in deficit when the type of toilet facility does not have a proper connection to sewerage (either sewerage system or septic tank. In those cases where toilet facilities are not connected to sewerage, the household is assigned a 1, and 0 otherwise.

$$Garbage = \begin{cases} 1 \; if \; no \; garbage \; collection \\ 0 \; otherwise \end{cases}$$

Finally, access to proper collection of waste or garbage could be associated with optimal habitational environmental conditions.[15] Deficit in garbage collection could be associated with a lack of proper housing environment, affecting suitable living conditions. Households reporting no garbage collection (including burning, burying, dumping in rivers, etc) will be assign 1 in the dataset and 0 otherwise.

Following these rules and households' compliance, the share of them under qualitative deficit, relative to the total number of households at the regional level is defined as:

$$QualiHD_j = \frac{\sum_i (W_{ij \; where=1} \; OR \; R_{ij \; where=1} \; OR \; O_{ij \; where=1} \; OR \; L_{ij \; where=1} \; OR \; U_{ij \; where=1})}{total \; households_j}$$

Where the numerator is defined by the sum of all households *i* in region *j* that indicate they have walls OR roofs made of non-durable materials OR are living in overcrowding, OR lack access to electricity, OR access to utilities (for the sake of equation space, $U_{ij \; where=1}$ incorporates adequate access to water, OR sanitation, OR garbage collection). A household assigned 1 for any of these indicators, will be considered in qualitative housing deficit. The denominator is the total number of households in region *j*.[16]

[15] This particular information is collected by the Guyana's census as one of the questions in the facilities available for use. Other potential variables related to conditions outside dwelling could be distances to work, nearest school, hospital or health center, and availability of public streetlighting.

[16] Note that, in this case, neither qualitative nor quantitative is divided by a regional characteristic like urban or rural, costal or interior, given that there is no specific variable available in Guyana's census to discriminate on these criteria. In the case there is a way to determine regional characteristics like cultural division, or rural or costal classifications, and the rules' set is available, what is called here "region *j*" can be adjusted to the selected identification.

V. USING PUBLIC GIS AND SATELLITE INFORMATION TO ESTIMATE HOUSING DEFICIT

Access to proper public amenities like public lighting, adequate roads, schools, and hospitals, provide additional insight into the housing deficit. Apart from a household's own access to electricity, piped water, and adequate sewerage systems, a household's neighborhood also comprises an important part of its conditions. Lack of public lighting could indicate risks related to crime, lack of schools would imply less access to education, and poorly paved roads would cause an increase in travel times from home to any destination, all of which reduce the quality of living for residents. These neighborhood indicators can provide a map across which to project data from contexts where conditions are known, to contexts where conditions are yet unknown. This section explores using public lighting based on satellite imagery to predict housing conditions for years when census data is unavailable.

Recently, satellite imagery has been used as a rich source of information to study social issues related to poverty and inequality. A strong relationship has been found between night lights and the economic dynamic measured by GDP (NOAA, 2010) and poverty (Engstrom, et.al, 2017); satellite information has been found useful in the detection of slums (Divyani, et.al, 2016) and prediction of housing prices (Bency, et.al, 2017).

To estimate an 'update' of the housing deficit in 2019 based on census data from 2012, this note will demonstrate how the methodology designed by Henderson et.al, 2012, using night lights to estimate economic growth, can be successfully applied to estimate qualitative housing deficit in Guyana. The process incorporates the estimations of qualitative housing deficit based on Guyana's 2012 Census data (from section IV) and satellite information on nighttime lights.

The reasoning behind the use of night light data is that the level of luminosity detected by sensors could be associated with the level of urban development (Muzzini, et.al, 2016) in each region. Qualitative housing deficit, found to be the primary driver of total housing deficit, has been measured with rules derived from the availability of public services or utilities, variables that correlate with the presence or absence of public infrastructure like street lighting. Exploiting this relationship between dwellings' access to services and luminosity would help to understand the behavior of qualitative housing deficit in areas or periods of time where and when no statistical microdata is available. In this study, since the most recent census in Guyana was implemented in 2012, the idea is to use nightlight data to estimate the size and distribution of qualitative deficit in 2019 using data from 2012.[17]

[17] The nighttime lights data is not the only data that could be used for such a prediction. Depending on availability, it is possible to also include data on availability of schools and hospitals (from OpenStreetMap) to determine access to services that correlate with health and education levels. In this case, reliable OpenStreetMap data was not available from 2012 in Guyana. Also, information from satellite imagery that contains data on the reflectance of roads could provide information about road

Three sets of data are needed to implement the methodology: qualitative deficit estimations for the base year, luminosity data from the base year, and luminosity data from the target year. Estimation of 2012 qualitative deficit by NDCs can be obtained from the 2012 census. Nighttime lights data for the same period as census estimation (in this case 2012), and also for the target year of prediction (in this case 2019) can be downloaded from the Visible Infrared Imaging Radiometer Suite (VIIRS).[18]

Three estimations must be done to implement this methodology in this particular setting.[19]

First, using the census data and the defined set of rules, the figures for qualitative deficit as it was addressed in the previous section must be estimated.

Second, the level and significance of the relationship between the figures obtained in the previous step and the nighttime lights data must be estimated. This particular estimation will validate (through a test of statistical significance) that the reasoning explained above is applicable to this problem. The econometric model used in this second step is the following:

$$QualD2012_i = \beta_1 + \beta_2 L2012_i + \varepsilon \qquad (1)$$

Where $QualD2012_i$ is the variable that contains the qualitative deficit for region *i*.[20] β_1 is the intercept and the parameter of interest is β_2, which accompanies $L2012_i$, or the mean value of observed nighttime light in region *i*. Finally, ε is an error term. The estimation process of this model produces the estimated values for the parameters and the error term, namely $\widehat{\beta_{1,2012}}$, $\widehat{\beta_{2,2012}}$, and $\hat{\varepsilon}_{2012}$, respectively. In particular, and consistently with the assumption, it is expected that $\widehat{\beta_{2,2012}}$ will be negative and statistically significant since an increase in luminosity should be correlated with a decrease in qualitative housing deficit.

The third and last estimation is to predict the levels of qualitative deficit in 2019. At this point, the only way to obtain figures for qualitative deficit in 2019 is through predicting those values using the nighttime light information in 2019 with the parameters obtain in equation 1. The process is summarized by the following equation:

$$PQD2019_i = \widehat{\beta_{1,2012}} + \widehat{\beta_{2,2012}}\, L2019_i + \hat{\varepsilon}_{2012} \qquad (2)$$

characteristics like pavement status such that the density of unpaved/paved roads at the region level would provide insight on the level of public infrastructure and how this correlates with qualitative deficit. Again, in the case of Guyana adequate information was not identified for this study, but could be incorporated in future iterations, or in other contexts.

[18] https://ngdc.noaa.gov/eog/viirs/download_dnb_composites.html. This data goes from 2012 month by month up to 2019.

[19] The process implies to convert satellite data into statistical data able to be combined with data coming from census. This process involves use of GIS packages (QGIS or ArcGIS, in others) to convert satellite data in tabulated data.

[20] Note that region could be replaced by whatever level at which the analysis is desired.

Where $PQD2019_i$ is the predicted qualitative deficit value in 2019 for region *i*, obtained using the estimated parameters $\widehat{\beta_{1,2012}}$, $\widehat{\beta_{2,2012}}$, and $\hat{\varepsilon}_{2012}$ in addition to the mean value of nighttime light in region *i* for 2019, $L2019_i$. The result of the exercise is summarized in the following tables.

Table 4. Results for estimation of equation 1 for qualitative deficit.

```
      Source |       SS           df       MS      Number of obs   =       116
-------------+----------------------------------   F(1, 114)       =     36.63
       Model |  .997844872         1  .997844872   Prob > F        =    0.0000
    Residual |  3.10583784       114  .027244192   R-squared       =    0.2432
-------------+----------------------------------   Adj R-squared   =    0.2365
       Total |  4.10368272       115  .035684198   Root MSE        =    .16506

------------------------------------------------------------------------------
   def_quali |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
mean_light_2012 |  -.0457706   .007563    -6.05   0.000    -.0607528   -.0307884
       _cons |   .9645429   .0209016    46.15   0.000     .923137    1.005949
------------------------------------------------------------------------------
```

Source: Own calculations and Guyana's 2012 census data.

Table 4 and 5 present the results of the estimation of equation 1. The parameter of interest is "mean_light_2012" in both equations. As expected, the parameter is negative and statistically significant which means that the relationship between nighttime lights and the qualitative and total housing deficit follows the reasoning expose in lines above.

Table 5. Results for estimation of equation 1 for total housing deficit.

```
      Source |       SS           df       MS      Number of obs   =       116
-------------+----------------------------------   F(1, 114)       =     35.04
       Model |  .911515794         1  .911515794   Prob > F        =    0.0000
    Residual |  2.96554051       114  .026013513   R-squared       =    0.2351
-------------+----------------------------------   Adj R-squared   =    0.2284
       Total |  3.8770563        115  .033713533   Root MSE        =    .16129

------------------------------------------------------------------------------
   total_def |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
mean_light_2012 |  -.0437459   .0073902    -5.92   0.000    -.0583857   -.029106
       _cons |   .9642084   .0204241    47.21   0.000     .9237484    1.004668
------------------------------------------------------------------------------
```

Source: Own calculations and Guyana's 2012 census data.

Table 6 presents the values for the prediction using equation 2 and a comparison between 2012 deficit and the predicted 2019 deficit. On average it seems that the situation is not improving at the national level, however Region 1, 2, 5, 8, 9 (some of which are in the

hinterland and with poverty figures above the national mean) are improving. Since this estimation is taken in relative terms (regression compares the deficits across country relative to nighttime light) it could happen that Region 4 (Georgetown area) is not worsening but the other regions are improving at a higher rate (urbanizing faster than Georgetown area, and therefore registering more light).

Table 6. Housing deficit nationally and by region predicted for 2019 (equation 2).

Characteristics	National (%)	Regions (%) 1	2	3	4	5	6	7	8	9	10
Households in deficit (Predicted 2019)	**88.36%**	**89.57%**	**91.85%**	**86.36%**	**74.94%**	**90.48%**	**91.44%**	**89.06%**	**92.31%**	**88.46%**	**89.11%**
Households in qualitative deficit (Predicted 2019)	**87.93%**	**89.19%**	**91.60%**	**85.85%**	**73.86%**	**90.16%**	**91.17%**	**88.66%**	**92.07%**	**88.04%**	**88.71%**
Households in deficit (2012)	86.53%	99.80%	96.93%	74.52%	53.45%	95.01%	84.30%	87.33%	97.80%	98.18%	78.01%
Households in qualitative deficit (2012)	86.04%	99.80%	96.86%	73.76%	51.01%	94.84%	83.89%	86.86%	97.66%	98.09%	77.61%
Households in deficit (Difference)	1.83%	-10.24%	-5.07%	11.85%	21.49%	-4.53%	7.15%	1.72%	-5.48%	-9.72%	11.11%
Households in qualitative deficit (Difference)	1.89%	-10.61%	-5.27%	12.09%	22.84%	-4.68%	7.27%	1.81%	-5.59%	-10.05%	11.11%

Source: Original construction based on DANE (2009) and own calculations based on Guyana's 2012 census data and nighttime light data in 2012 and 2019.

Lastly, the performance of the predictions seems to behave well. Table 7 shows the Coefficient of variation and as can be seen values are low meaning high statistical accuracy.

Table 7. Coefficient of variation for prediction.

Characteristics	National (CV)	Regions (CV) 1	2	3	4	5	6	7	8	9	10
Households in deficit (Predicted 2019)	**0.057**	**0.12**	**0.04**	**0.09**	**0.25**	**0.04**	**0.08**	**0.13**	**0.06**	**0.07**	**0.11**
Households in qualitative deficit (Predicted 2019)	**0.060**	**0.12**	**0.04**	**0.09**	**0.27**	**0.04**	**0.08**	**0.14**	**0.06**	**0.07**	**0.12**

Source: Original construction based on DANE (2009) and own calculations based on Guyana's 2012 census data and nighttime light data in 2012 and 2019.

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VII. Annex

Indicators	Census's variable used	Options	Deficit (1=Yes, 0=No)
Inadequate	H1.1 What type of building is	1 Residential	0
		2 Residential/Commercial	0
		3 Residential/Office	0
		4 Community Service	1
		5 Other (specify)	1
	H2.2 What type of dwelling	1 Separate house/Detached	0
		2 Part of a private house/Attached	0
		3 Flat/Apartment/Condominium	0
		4 Townhouse	0
		5 Double house/Duplex	0
		6 Combined business & Dwelling	0
		7 Barracks	1
		8 Makeshift	1
		9 Other	1
Wall material	H1.2 What is the main 1 0	1 Wood	0
		2 Concrete	0
		3 Wood & Concrete	0
		4 Stone	0
		5 Adobe & Troolie Palm	1
		6 Makeshift	1
		7 Brick only (Clay Brick)	0
		8 Stone and brick	0
		9 Galvanize	1
		10 Wood & Brick	0
		11 Other (specify)	1
Roof material	H1.3 What is the main	1 Sheet metal (zinc, aluminium, galvanize)	0
		2 Shingle (asphalt)	0
		3 Shingle (wood)	0
		4 Shingle (other)	0
		5 Tile	0
		6 Concrete	0
		7 Thatched/Troolie Palm	1
		8 Makeshift	1
		9 Other (specify)	1
Cohabitation	Dewlling id and Household id	One household living in dwelling	0
		More than one household sharing	1
Overcrowding	Total number of people in		
	H4.7 How many rooms does	less than 3 people per room	0
		3 or more people per room	1
Acute	H4.8 How many bedrooms are	less than 5 people per room	0
		5 or more people per room	1
Acces to services	H4.2 What is the main source	1 Gas Lantern	1
		2 Kerosene	1
		3 Electricity (Public)	0
		4 Electricity (Private)	0
		5 Solar/Inverter	0
		6 Other (specify)	1
Acces to services	H4.3 What is the main source	1 Private, piped into dwelling	0

		2 Private catchments/rain water	0
		3 Private, piped into yard/plot	0
		4 Public, piped into dwelling	0
		5 Public, piped into yard/plot	0
		6 Public standpipe or hand pump	0
		7 Public well	0
		8 Spring/river/pond	1
		9 Truck borne	0
		10 Dug well/borehole	0
		11 Other (specify)	1
	H4.4 What is the main source	1 Piped into dwelling	0
		2 Piped into yard/plot	0
		3 Public standpipe	0
		4 Tube-well/borehole with pump	0
		5 Protected dug well/spring	0
		6 Bottled water	0
		7 Rain water collection	1
		8 Unprotected dug-well/spring	1
		9 Pond/river/stream	1
		10 Vendor/private supplier	0
		11 Other (specify)	1
Sewerage	H4.5 What type of toilet	1 W.C. (Flush toilet) linked to sewer	0
		2 W.C. (Flushtoilet)linkedtoseptictank/soak-away	0
		3 Ventilated Pit Latrine (VIP)	1
		4 Trad. Pit Latrine with slab	1
		5 Trad. Pit Latrine w/out slab	1
		6 None	1
		7 Other (specify)	1
Garbage	H4.9 How does this household	1 Dumping on land	0
		2 Compost	0
		3 Burning	1
		4 Dumping/throwing into river/sea/pond	1
		5 Burying	0
		6 Garbage truck/skip/bin - Public	0
		7 Garbage truck - Private	0
		8 Other (specify)	1

Table A1. Dummy variables for deficit defined based on Guyana's 2012 census