< BACK TO MAP OF THE MONTH (/OUTPUTS/MAP-OF-THE-MONTH/)

Building volume per person in Gauteng

Dr Laven Naidoo (/about/staff) (http://orcid.org/0000-0002-7091-0566),
Dr Richard Ballard (/about/staff) (https://orcid.org/0000-0001-6244-6946),
Yashena Naidoo (/about/staff) (https://orcid.org/0000-0003-3171-448X), Gillian Maree (/about/staff)
(https://orcid.org/0000-0002-7952-6659), Dr Samkelisiwe Khanyile (/about/staff)
(https://orcid.org/0000-0002-7620-7628), Dr. Daniela Palacios Lopez (DLR), Dr. Thomas Esch (DLR)

DOI: https://doi.org/10.36634/MFZU7642
(https://doi.org/https://doi.org/10.36634/MF

Date of publication: 03 July 2023

Download Map
(Https://D3iy114y1zl2zq.Cloudfront.Net/Media/Documents/BVPP_MoTM_July_download.Pdf)

Unveiling Housing Disparities: Leveraging Earth Observation and population data to estimate Building volume per person in the Gauteng City Region

One way in which apartheid's inequalities manifest in urban space is that some people have much more building space to live in than others. In wealthier suburban areas, it is normal for a household of four people to occupy a house of three bedrooms, a kitchen, a living room and multiple bathrooms. In townships, however, people share living space much more intensively. Apartheid-era 'four room' houses provide a much smaller building volume often for a larger number of residents. In the final decades of apartheid, the state did not supply sufficient housing in townships and demand was met through overcrowding of existing housing stock, the construction of backyard dwellings and the emergence of informal settlements (Crankshaw, 2022). Low cost housing provided in the democratic era as part of the RDP housing and Human Settlements programmes are extremely economical with building size. State funded low cost housing has only partly met housing demand among low income residents, and the construction of additional small dwellings in backyards and informal settlements continues to play a key role in meeting demand (Hamann, Mkhize and Götz 2018, Lemanski 2009, Turok & Borel-Saladin, 2015).

Average residents per room

One way of quantifying this variation is to use the GCRO's Quality of Life Survey data to divide the number of people in each household by the number of rooms occupied by each household (i.e. crowding measurement). This data shows that on average, there are 1.41 people to a room (excluding bathrooms, toilets or kitchens) in Gauteng. For 56% of the respondents, the number of people in the household is equal to, or less than, the number of rooms, meaning that each person has one room each or more (Figure 1; orange highlighted area). For the remaining 44%, the number of people in the household exceeds the number of rooms, meaning that each person has less than one room each. A subset of this second group shares space more intensively; for a quarter of the households, there is a ratio of two or more household members for every room (Figure 1; purple highlighted area). The most extreme case reported was 16 people per room.

Number of occupants per room in households across the Gauteng City Region

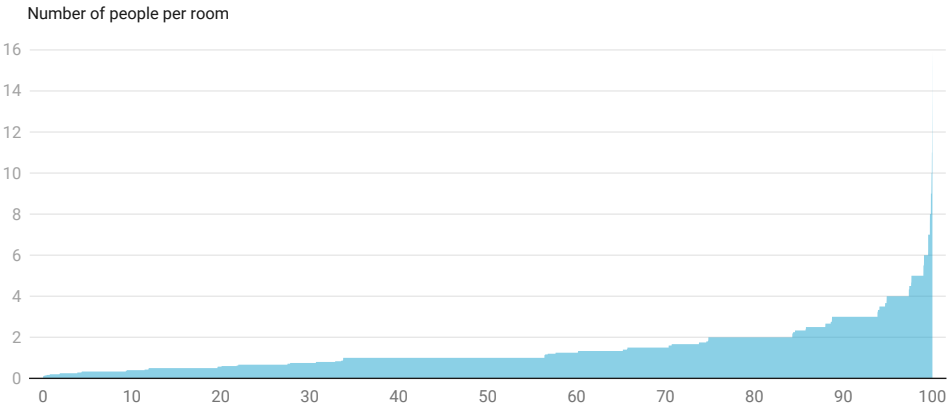

Chart: Laven Naidoo • Source: Quality of Life Survey 6 • Get the data • Embed • Download image • Created with Datawrapper

Figure 1: Number of occupants per room in households across the GCR shown as a cumulative percentage. Data source: GCRO Quality of Life survey 6 (2020/21) (https://www.gcro.ac.za/research/project/detail/quality-life-survey-vi-202021/).

Mapping building volume per person

The limitation of the QoL 6 (2020/21) survey data is that we don't know the size of a room. It would be useful to know in more precise terms the ratio between population density and building volume. While generating a measure of building volume by physically calculating the volume of each building would be impossible for this city region, Earth Observation techniques allow us a different way of measuring building volume (e.g. Reddy and Leslie 2015 and Ghosh et al. 2020). The German Aerospace Centre (DLR) recently provided the GCRO with the WSF3D dataset for the area of Gauteng. The WSF3D is a global dataset that provides accurate quantification of the building area, fraction, height, and volume, derived from satellite imagery and radar remote sensing. In Figure 2 we represent an estimate of the ratio of building volume per capita. This was derived by combining the WSF3D's building volume estimates with estimates of population from GeoTerraImage (GTI), with both datasets organised into a layer of 400m corner-to-corner hexagons covering the whole of Gauteng.

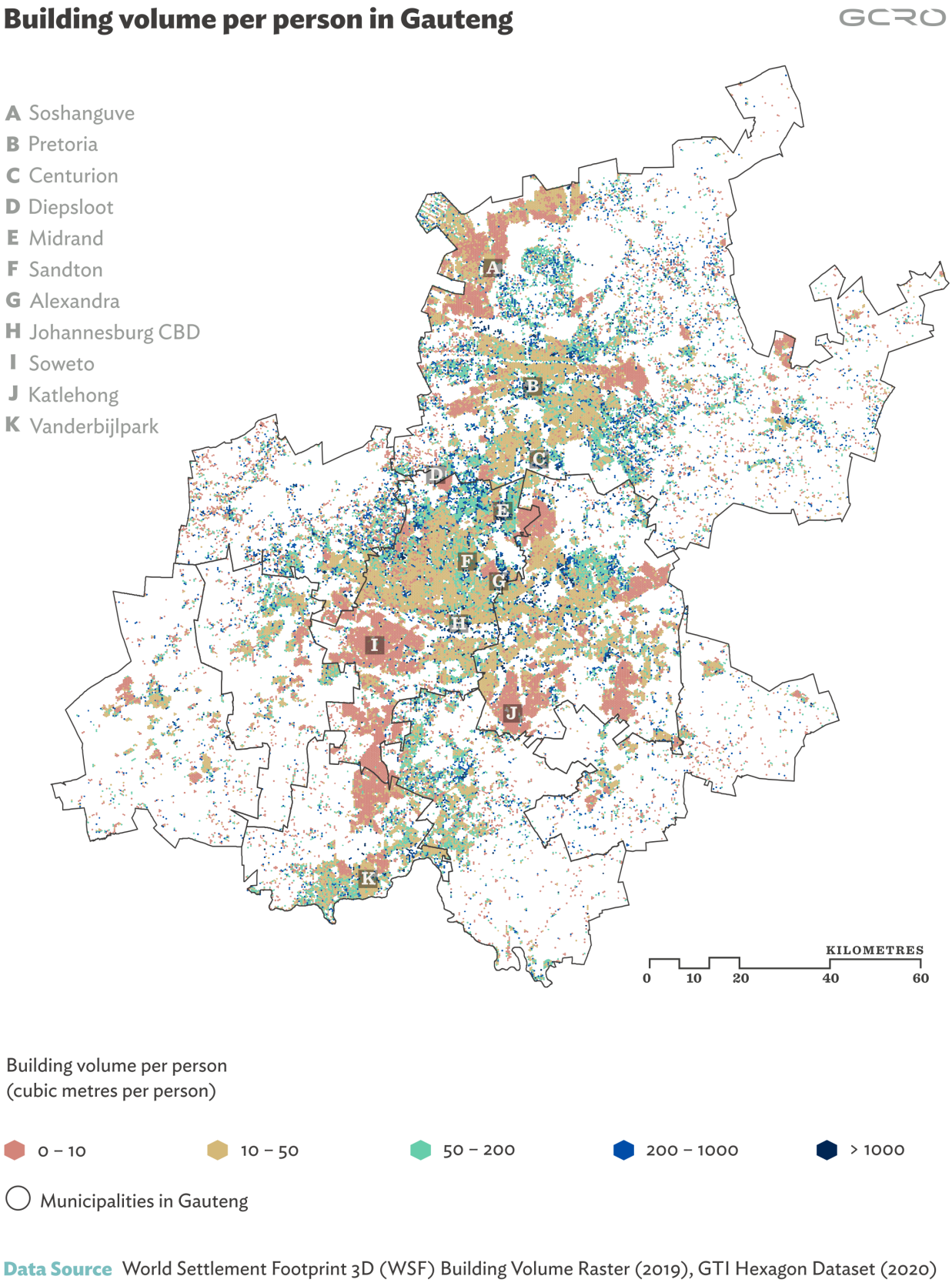

Figure 2: Building Volume Per Capita (cubic metre per person) map for the Gauteng City Region

The resulting map provides a dramatic impression of urban inequality. Many residents of Alexandra, Soweto, Katlehong, Diepsloot, Tembisa, Soshanguve, Daveyton, Tsakane, Khutsong and other townships and informal settlements have the lowest volume available per person (< $10m^3$ per person). These are areas shaded peach on the map. By comparison, residents in areas shaded yellow have between 10 and 50 cubic metres (for example, parts of Soshanguve (A) and most of Vanderbijlpark (K)). In turquoise coloured areas, such as parts of Midrand (E) and parts of Pretoria East (specifically Olympus and Silver Lakes), the building volume ranges between 50 and 200 cubic metres per person. Moderate (50 - $200m^3$ per person) to moderately low (10 - $50m^3$) building volume per person was observed in city centres of the main urban nodes across Gauteng, such as

Pretoria, Centurion and Johannesburg which are indicative of the high rise but densely populated blocks of flats historically situated in these city centres. Moderate (50-200m^3) building volumes per person are also more consistent within newly developed city nodes such as Midrand, which are dominated by duplex and townhouse styled housing.

In blue areas, such as Waterfall and Modderfontein, the building volume ranges from 200 to 1000 cubic metres per person. Finally, navy blue coloured areas, such as parts of Sandton (F), large security/golfing estates and the northern suburbs of Johannesburg, illustrate areas which have more than 1000 cubic metres of building volume per person. High (200 - 1000m^3) to very high (> 1000m^3) building volumes per person were specifically observed in the wealthier parts of Gauteng. Such areas are characterised by large spacious detached housing with a small number of occupants and noticeable separation between housing units/plots. The area with no values on the map represent areas which either did not have building volume data or population data and can refer to landscape features such as open veld, green infrastructure, water bodies and commercial and industrial areas where no occupants were recorded.

Overall, this simple building volume per person metric quickly outlines the level of housing inequality across Gauteng, while also hinting at the possible structure of these housing types. Additionally, being a 3D metric, building volume per person can account for occupants located within the vertical profile of housing buildings as well as the occupants spread horizontally across the landscape which is evident in most 2D derived metrics.

A detailed view of building volume per person

Figure 3A, below, illustrates this disparity in available living space per person with the Alexandra township illustrating the lowest values with surrounding affluent suburbs such as Sandton, Modderfontein and Greenstone illustrating the highest values. Figure 3B illustrates an example of urban densification in Katlehong which has a large concentration of backyard shack dwellings and a resultant of building volume per person of less than 10m^3. Figure 3C, illustrates the disparity in building volume per person between a well established and historic township, Soshanguve, and the surrounding private farm holdings. Unlike more dense townships such as Alexandra, Soshanguve displays an overall greater building volume per person (10 - 50m^3) with pockets of very low building volume per person (less than 10m^3). This township, however, contrasts greatly with the large private farm holdings, found to the east, in the settlement of Honingnestkrans which indicates a very high building volume per person. These figures illustrate how heterogeneous and complex Gauteng is with stark differences in housing equity over short distances and adjacent neighbourhoods.

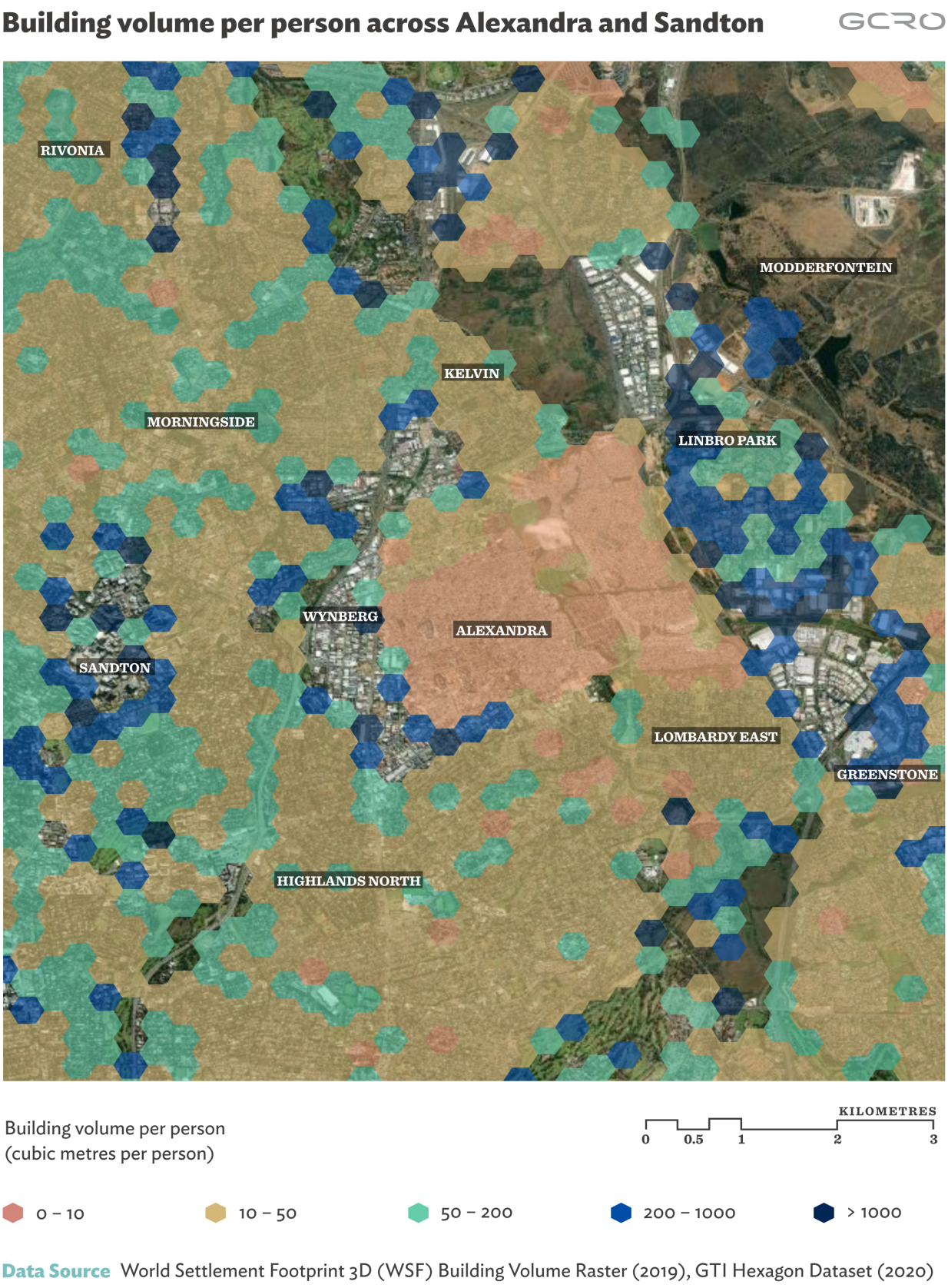

Figure 3A: Building volume per person (cubic metre per person) map across Sandton, Alexandria, Modderfontein & Greenstone

Figure 3B: Building volume per person (cubic metre per person) map across Katlehong and Vosloorus

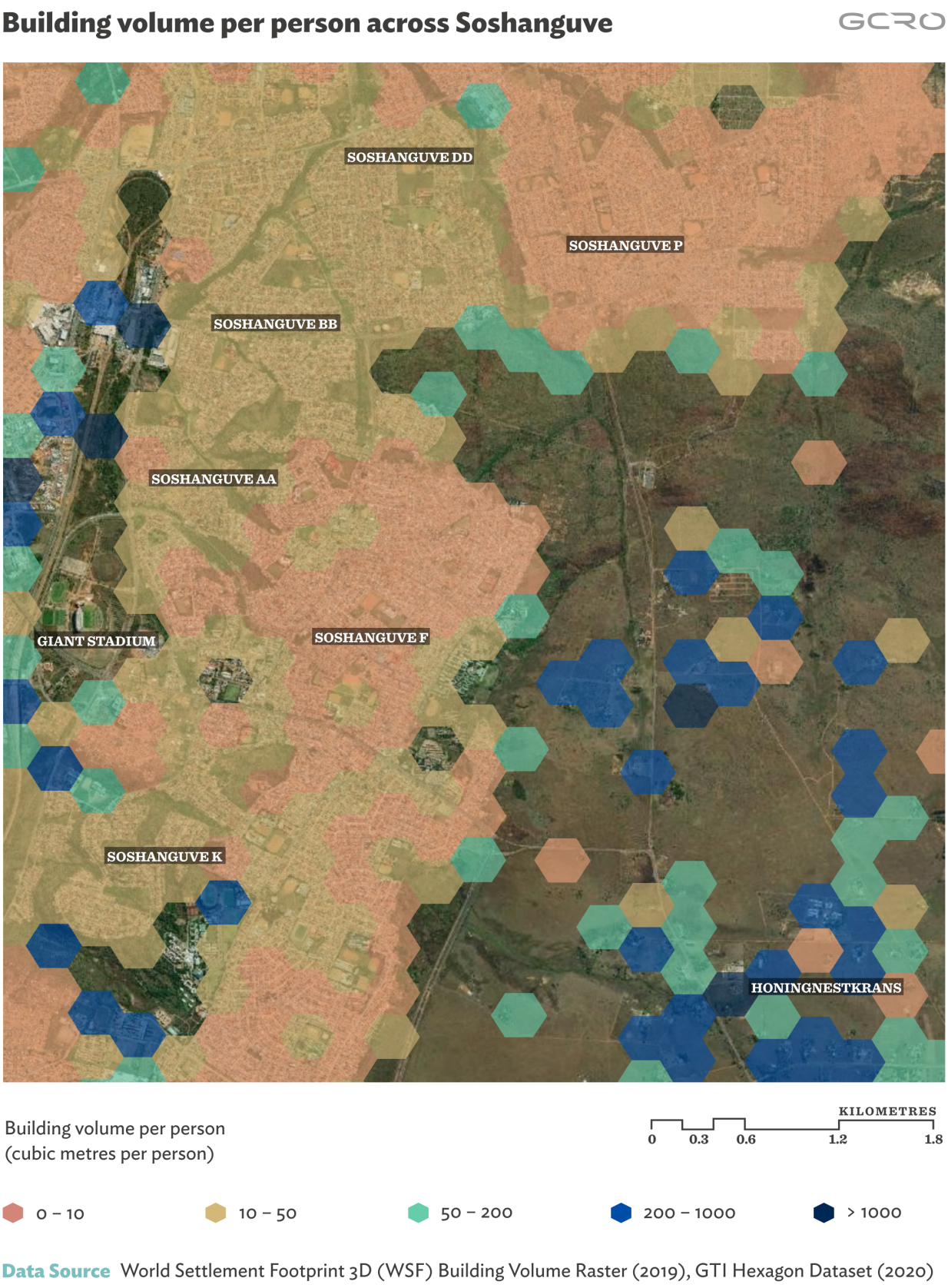

Figure 3C: Building volume per person (cubic metre per person) map across Soshanguve and peripheral areas

Overcrowding as a social issue

Density can be positive in some respects but negative in others (see earlier publications on density such as Parker and Hamann 2020 (https://www.gcro.ac.za/outputs/map-of-the-month/detail/most-densely-populated-areas-gauteng/)). Intensive use of space yields many efficiencies, for example the provision of infrastructure is more cost effective. On the other hand, density becomes a burden when people have to live

in overcrowded conditions, and it is generally low-income groups that bear this burden. Apart from being a constitutional right outlined in Section 26 of the Constitution (Constitution of the Republic of South Africa, 1996), access to adequate and equitable housing has been also globally recognised under the gazetting of the United Nations Sustainable Development Goals in 2015. This specifically pertains to SDG 10 regarding reducing inequalities in urban landscapes and SDG 11, which deals with sustainable cities and communities in general (UN General Assembly, 2015). Overcrowding was identified as a key aspect that increase vulnerability to the spread of COVID-19 in GCRO's work (https://gcro.ac.za/outputs/map-of-the-month/detail/mapping-vulnerability-to-covid-19/) during the pandemic where a crowded dwelling was defined as 3 or more individuals per functional room, as well as any single-room dwelling shared by multiple households. By this measure about 14.4% of all respondents in Gauteng live in crowded dwellings (de Kadt et al, 2020).

To interrogate this picture further, income levels modelled by GeoTerra Image (GTI) and the total number of households at the hexagon level, were used to extract the corresponding range of building volume per person values. The income levels results are illustrated in Figure 4 below.

Percentage Total Building Volume per Person and Number of Households Per Annual Income Group

	% Share of Total Building Volume per Person	% Total of households
R 0 to R 28 550	4.56	17.21
R 28 551 to R 64 620	8.42	41.80
R 64 621 to R 140 100	25.86	12.69
R 140 101 to R 245 400	25.28	7.46
R 245 401 to R 363 950	7.09	5.91
R 363 951 to R 490 850	14.07	6.19
R 490 851 to R 756 100	8.48	5.43
R 756 101 to R 1 189 000	3.48	2.08
R 1 189 001 to R 1 952 000	2.54	1.13
R 1 952 001 and more	0.22	0.10

Chart: Laven Naidoo • Source: World Settlement Footprint 3D Building Volume (2019); GTI Hexagon Dataset (2020) • Get the data • Embed • Created with Datawrapper

Figure 4: Percentage total Building Volume per Person (cubic metre per person) and total number of households per annual income group

When intersected with the total number of total households and annual income group data, the building volume per person values across Gauteng is showing some sobering results. According to Figure 4, a total annual income of less than R64 620 (considered to be both poor and low emerging categorisations of households) consists of roughly 60% of total households but only 13% of the total building volume per capita across Gauteng (this is a combination of the first two rows in Figure 4). This confirms that lower income groups in Gauteng live in the densest conditions. Roughly 50% of the accumulative building volume per person is found in households with lower-middle to middle-income groups which account for 19% of the total households in Gauteng (this is a combination of the third and fourth rows in Figure 4). The upper-income groups (including the very wealthy), though having lower overall cumulative percentage values, generally share a higher percentage of total building volume per person than the total percentage of households.

National housing code: adequate housing

According to the National Housing Code 2009 (NHC), adequate housing is defined as a living area of approximately 40m². We can then conservatively assume that the living space has an average height of 2m. With these figures in mind, if these buildings house the statistical average number of people per household, according to StatsSA (General Household Survey (GHS), 2021), of 3.34, the measure of a building volume per person suitable for adequate housing can be calculated as follows:

Adequate housing building volume per person = (40m² housing area X 2m house height)/3.34

= 24m^3 per capita

Using this statistic, we can surmise that approximately 49% of households in Gauteng (sampled in this study's dataset) are living in inadequately small housing conditions.

Methods:

The 2019 building volume raster layer was obtained from the German Aerospace Centre (DLR) whose scientists developed this dataset, together with other building structural metrics, as part of the World Settlement Footprint 3D (WSF) dataset suite across the globe. The World Settlement Footprint 3D was generated using a modified version of the WSF human settlements mask (derived from Sentinel-1 and Sentinel-2 satellite imagery) in combination with digital elevation data and radar imagery collected by the TanDEM-X mission (Esch et al., 2022). The building volume dataset was developed at a spatial resolution of 90m and volume was represented at the cubic metre. The population dataset was obtained from the GeoTerraImage (GTI) Hexagon Dataset of 2020. The dataset was remodelled from the Enumeration Area (EA) to hexagons and was informed by census population data. Each 'pixel' is a hexagon with an area of 0.103755 km². The population hexagon shapefile was used to extract the summed building volume (m^3) raster cell values contained with each hexagon. The building volume per person metric was subsequently calculated by dividing the summed building volume by the total population per hexagon to ascertain the amount of building volume (m^3) allocated per person. Income

levels, represented as codes 1-10 in the Neighbourhood Lifestyle Index (NLI), were obtained at the hexagon spatial resolution, also sourced from the GTI Hexagon Dataset of 2020. The authors are aware that an edge effect of inflated building volume per person can occur at the interface of the urban footprint and an abrupt change in land use. For example, fewer small houses with a low population count occurring in close proximity to malls may result in a much larger building volume per person than what could be expected.

References:

Constitution of the Republic of South Africa, 1996

Crankshaw O. 2022. Urban Inequality: Theory, Evidence, and Method in Johannesburg, Bloomsbury Publishing, London, 1–129 pp.: ISBN 9781786998941

Department of Human Settlements (2009). National Housing Code of South Africa, 2009. Available online at: https://www.dhs.gov.za/content/national-housing-code-2009.

De Kadt, J., Gotz, G., Hamann, C., Maree, G., and Parker, A. 2020. 'Mapping vulnerability to COVID-19 in Gauteng', GCRO Map of the Month, March. Available online at: https://gcro.ac.za/outputs/map-of-the-month/detail/mapping-vulnerability-to-covid-19.

Esch, T., Brzoska, E., Dech, S., Leutner, B., Palacios-Lopez, D., Metz-Marconcini, A., Marconcini, M., Roth, A., Zeidler, J. 2002. World Settlement Footprint 3D - A first three-dimensional survey of the global building stock. Remote Sensing of Environment, 112877, 1-15

General Household Survey. 2021. Statistics South Africa

Ghosh, T., Coscieme, L., Anderson, S.J., Sutton, P.C. 2020. Building Volume Per Capita (BVPC): A spatially explicit measure of inequality relevant to the SDGs. Frontiers in Sustainable Cities, 2 (37), 1-11. DOI: 10.3389/frsc.2020.00037.

Hamann, C., Mkhize, T., Götz, G. 2018. Backyard and informal dwellings 2001-2016. GCRO Map of the Month, February. Available online at: https://www.gcro.ac.za/outputs/map-of-the-month/detail/backyard-and-informal-dwellings-2001-2016.

Lemanski, C. 2009. Augmented informality: South Africa's backyard dwellings as a by-product of formal housing policies. Habitat International, 33, 472-484.

Parker, A., Hamann, C. 2020. The most densely populated areas of Gauteng. GCRO Map of the Month, April. Available online at: https://www.gcro.ac.za/outputs/map-of-the-month/detail/most-densely-populated-areas-gauteng.

UN General Assembly. 2015. Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1. Available online at: https://www.refworld.org/docid/57b6e3e44.html.

Reddy, A., Leslie, T. 2015. Volume per capita as a useful measure of residential space. Urban Geography, 36 (7), 1099-1112. DOI: 10.1080/02723638.2015.1060696.

Turok, I., Borel-Saladin, J. 2015. Backyard shacks, informality and the urban housing crisis in South Africa: stopgap or prototype solution? Housing Studies, 31 (4), 384-409.

Edits and input: Graeme Götz.

Map design: Jennifer Murray.

Suggested citation: Naidoo, L., Ballard, R., Naidoo, Y., Maree, G., Khanyile, S., Palacios Lopez, D. and Esch, T. (2023). Unveiling housing disparities: Leveraging Earth Observation and population data to estimate building volume per person Gauteng. Map of the Month. Gauteng City-Region Observatory. July 2023. https://doi.org/10.36634/MFZU7642.

Staff (/about/staff/)

Research Associates (/about/research-associates/)

Visitors & Interns (/about/about-visitors-interns-postdocs/)

Board (/about/board/)

Strategic Plans (/about/strategic-plans/)

Annual Reports (/about/annual-reports/)

RESEARCH

Research Themes (/research/research-themes/)

Data Analytics, Informatics & Visualisation (/research/research-themes/detail/data-analytics-informatics-and-visualisation)

Governing the GCR (/research/research-themes/detail/governing-gcr)

Histories & Futures (/research/research-themes/detail/histories-futures)

Inclusive Economies (/research/research-themes/detail/inclusive-economies)

Poverty, Inequality and Social Mobility (/research/research-themes/detail/social-mobility)

Social Change (/research/research-themes/detail/social-change)

Spatial Transformation (/research/research-themes/detail/spatial-transformation)

Sustainability and Just Transitions (/research/research-themes/detail/sustainability-transitions)

Understanding Quality of Life (/research/research-themes/detail/quality-life)

Government Support (/research/research-themes/detail/government-support)

OUTPUTS

Books (/outputs/books/)

Research Reports (/outputs/research-reports/)

Occasional Papers (/outputs/occasional-papers/)

Data Briefs (/outputs/data-briefs/)

Provocations (/outputs/provocations/)

Academic Publications (/outputs/academic-publications/)

Profiled Articles (/outputs/profiled-articles/)

Presentations (/research/presentations)

Photo Essays and Videos (/outputs/photo-essays/)

Vignettes (/outputs/vignettes/)

Map of the Month (/outputs/map-of-the-month/)

Policy and Other Outputs (/outputs/policy-and-other-outputs/)

Datasets (/outputs/datasets/)

Media (/outputs/media/)

Catalogue (/outputs/catalogue/)

URBAN DATA GALLERY

Overview (/data-gallery/overview/)

QoL Viewer (/data-gallery/quality-of-life/)

Barometer (http://barometer.legacy.gcro.unomena.net/)

State of the GCR (/data-gallery/state-of-the-gcr/)

Image Gallery (/data-gallery/image-gallery/)

Interactive Visualisations (/data-gallery/interactive-data-visualisations/)

GIS Viewer (https://gcro1.wits.ac.za/gcrojsgis/)

Ward Profile Viewer (https://gcro1.wits.ac.za/wardprofileviewer/)

Urban Observatory (http://www.urbanobservatory.org/compare/index.html?group%3Df4373b6eae144e26a634937269d336ec%26noun%3DPeople%26theme%3DPopulation%2520Density%26cities%3DEkurhuleni%26cities%3DJohannesburg%26cities%3DTs)

Village of 100 people (https://village-of-100.gcro.ac.za/)

NEWS & EVENTS

News (/news-events/news/)

Events (/news-events/events/)

Newsletters (/news-events/newsletters/)

CONTACT

Contact Us (/contact-us/)

Go to Top ▲