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From Urban Extent to Urban Fabric: Remote Sensing Evidence for SDG 11

Magnus Andersson (magnus.e.andersson@mau.se), David Muthui and Reza Roodaki, Department for Urban Studies, Malmö University, Sweden

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Abstract

Two neighbourhoods can have same population density, urban extent but different urban fabric, should they be treated in a similar way in policy? Satellite imagery and remote sensing analysis can show which has high-rise, well-structured blocks and the other with dense, low-rise informal fabric. Remotely sensed information can therefore strengthen the implementation of Sustainable Development Goal (SDG) 11 by making horizontal and vertical urban change visible, measurable, and comparable across space and time. When land cover, building footprints, building height, population and construction materials information are analysed together, they provide a comprehensive account of how the built environment is expanding, densifying and consuming land and other resources. Remote sensing can be used to analyse exposure of residents to climate hazards, and create opportunities for more efficient, equitable, and resilient urban development. This enables governments to monitor densification, housing conditions, land-use efficiency and exposure to hazards in a consistent and comparable way. This combined evidence-based analysis is particularly valuable in data-poor or crisis-affected settings where cadastral records, building stock inventories, or survey data is incomplete, outdated, or inaccessible. By linking urban form typologies to building archetypes, the data can be used to estimate current material use, forecast future materials demand and debris generation. In addition, through modelling different development scenarios, we can incorporate low-carbon and circular construction strategies. The brief outlines how these capabilities can be integrated into national and sub-national SDG 11 monitoring systems and urban-planning workflows.

Introduction

SDG 11 calls for cities that are inclusive, safe, resilient and sustainable, requiring spatially explicit and reliable data on urban conditions (United Nations, 2015; UN-Habitat, n.d.). Conventional urban data systems often lack spatial resolution, temporal frequency, or territorial coverage needed for policy action (Angel et al., 2011). Many cadastral datasets are outdated or inconsistent, limiting governments' ability to monitor housing quality, land-use efficiency, exposure to hazards and environmental performance (UN-Habitat, 2021). This challenge is especially acute in rapidly urbanizing or climate-vulnerable settings, where remote sensing provides a consistent and scalable complement to official statistics (Andersson & Crnojevic, 2025).

This brief introduces an integrated approach combining land cover, building footprints, building height, population and construction-materials information to move from simple urban extent mapping toward a more policy-relevant understanding of the built environment.

What remotely sensed information adds to SDG 11 monitoring

Four complementary information layers are particularly important for understanding the built environment. Individually, each provides partial insight; combined, they offer a coherent representation directly actionable for SDG 11 monitoring (Ma et al., 2024; European Commission JRC, 2024) and enables more consistent comparisons across cities, regions and time periods.

Data layer	What it captures	Policy relevance for SDG 11
Land cover and built-up extent	Surface type, urban expansion, imperviousness, vegetation and open space	Supports land-consumption analysis, green-space monitoring, heat-risk assessment, and urban growth management.
Building stock footprints	Location, area size and distribution of structures	Enables settlement type mapping, service planning, housing estimates, and exposure analysis.
Building height from SAR, LiDAR, and related EO products and ML models	Vertical dimension, built volume and patterns of horizontal versus vertical growth	Enables more realistic measures of density, compactness, infrastructure demand and reconstruction scale.
Construction-material information	Likely roof, facade or structural materials and material intensity proxies	Adds insight on embodied carbon, retrofit potential, fragility, debris streams and circular-economy opportunities.

This integrated remote sensing perspective is particularly valuable in rapidly growing, data-poor or crisis-affected settings as it enables faster assessments of disaster aftershocks (Georgiou et al., 2022; Koks et al., 2019). Land-cover and built-up surface remote sensing products support the monitoring and evaluation of conversion of agricultural, wetlands and open spaces to urban use. This output is particularly important in informing the land-consumption component of SDG indicator 11.3.1 (UN-Habitat, 2021). Building stock footprint data complement this perspective by showing where structures are located and how settlement patterns vary across neighbourhoods including informal and peri-urban areas. At the same time, the growing availability of open-source building stock attribute products increasingly enables comparable spatial analysis across countries (European Commission, Joint Research Centre, 2024). Such comparability is essential for harmonized SDG 11 reporting and cross-country benchmarking.

Buildings height estimates deepen analysis of urban form from two-dimensional extent to a three-dimensional urban form. Synthetic aperture radar (SAR), spaceborne light detection and ranging (LiDAR) products provide attributes which is critical for understanding density, infrastructure demand and disaster exposure for example rising sea level especially for coastal cities. This allows for more robust estimates of density, usable floor-space and vertical growth patterns (Ma et al., 2024). Finally, emerging remote sensing methods for identifying material characteristics further enrich this discipline by supporting analysis of construction quality, embodied carbon, thermal performance and retrofit needs, (Rajaratnam et al., 2023; Sun et al., 2025) These material analysis enable estimates of material demand, supporting circular-economy planning and low-carbon construction pathways.

Why combining built form and construction materials matters

Assessments of the built environment based solely on urban extent or building counts often fails to capture the structural characteristics that determine vulnerability, resource demand and long-term sustainability (Taubenböck & Kraff, 2014; Kuffer et al., 2016). Cities are shaped not only by where buildings are located, but also by how much space they occupy vertically and by the materials from which they are constructed. Combining Urban extent, building counts and materials dimension yields a more policy relevant understanding of the urban fabric (Ma et al., 2024; Sun et al., 2025) because it links physical form to policy-relevant outcomes such as density, exposure, and material intensity. For policymakers, this means more accurate targeting of housing upgrades, infrastructure investment, risk-sensitive land-use planning and low-carbon construction strategies and to evaluate the trade-offs between horizontal expansion and densification by vertical growth.

This integrated approach matters for these reasons. First, it improves estimates of material stocks and embodied carbon by linking building characteristics to structural systems (Pauliuk & Müller, 2014; Huang et al., 2018) and material intensities which is essential for national material-flow accounts and SDG 12 reporting. Second, it strengthens risk assessments, as construction materials influence fragility, fire performance, thermal behaviour, and resistance to hazards (Koks et al., 2019; Georgiou et al., 2022) allowing authorities to prioritise risk-reduction investments. Third, it supports circular economy and reconstruction planning by enabling estimates of debris generation, salvageable materials and to plan post-disaster debris logistics more efficiently (Rajaratnam et al., 2023; O'Brien et al., 2020). Fourth, it enhances the capacity to compare neighbourhoods in terms of density, housing quality, and long-term resilience (Sun et al., 2025).

Implications for SDG 11 targets and indicators

Target 11.1 (Adequate, Safe, and Affordable housing): The combined information on urban form and materials can help identify areas with overcrowding and low-quality structures for example slums (Kuffer et al., 2016), weak thermal performance, or insufficient service provision (United Nations, 2015; UN-Habitat, n.d.). This enables national and local authorities to spatially target housing-upgrade programmes, social-housing investments, and basic-service extensions to vulnerable neighborhoods.

Target 11.3 (Inclusive and Sustainable Urbanization): Multi-temporal land cover, building footprints and heights data improve monitoring of land-use, densification, and urban sprawl (UN-Habitat, 2021; Ma et al., 2024). These insights support the design of policies for compact growth, transit-oriented development, and the protection of agricultural land and ecological corridors.

Target 11.5 (Disaster Risk Reduction): Exposure analysis becomes stronger when location and hazard overlays are complemented by building height and material-related fragility information (Koks et al., 2019; Georgiou et al., 2022), particularly for damage assessment and resilient reconstruction (United Nations, 2015; Andersson & Crnojevic, 2025). This allows governments and humanitarian actors to prioritize risk-reduction measures and post-disaster reconstruction in areas where vulnerable populations and fragile building types coincide.

Target 11.6 (Environmental Impact of Cities): Material stock and building-envelope characteristics can inform analysis of embodied emissions, urban heat, runoff water and retrofit priorities (Rajaratnam et al., 2023; Sun et al., 2025). In practice, this helps identify neighborhoods where targeted retrofit programmes, nature-based

solutions and drainage upgrades can deliver the greatest reductions in emissions, heat stress and flood risk.

Target 11.7 (Safe, Inclusive, and Accessible Green and Public Space): Built-up density and settlement morphology can be assessed alongside vegetation and open-space data to understand inequitable access to green and public spaces (United Nations, 2015; UN-Habitat, n.d.). Such analyses enable planners to map spatial inequalities and injustice in access to parks and public spaces and prioritize investments in underserved neighborhoods.

Policy Recommendations

1. Integrate remote-sensing-based built-environment metrics into official SDG 11 monitoring systems at national and local level, building on the global SDG framework and associated monitoring guidance (United Nations, 2015; UN-Habitat, n.d.).
2. Promote interoperable urban data that combine Earth observation with cadastral, census, infrastructure, and engineering datasets, including open building-attribute products where available (European Commission, Joint Research Centre, 2024).
3. Invest in local validation and calibration, since building typologies and construction materials vary significantly across countries, regions, and cities.
4. Move from two-dimensional built-up mapping toward three-dimensional and material-aware urban monitoring that can better inform resilience and low-carbon policy (Ma et al., 2024; Sun et al., 2025).
5. Use multi-temporal analyses to detect not only current urban conditions but also growth trajectories, densification, and reconstruction (Georgiou et al., 2022).
6. Apply combined urban form-and-material evidence to prioritize retrofit programmes, resilient reconstruction, circular construction strategies, and risk-sensitive land-use planning (Rajaratnam et al., 2023; Koks et al., 2019).
7. Use multi-temporal form-and-material evidence to estimate future material demand and support long-term planning for low-carbon construction (Pauliuk & Müller, 2014).
8. Integrate material-stock and debris generation estimates into circular-economy and resilient-reconstruction strategies (O'Brien et al., 2020)

Conclusion

To meet the ambitions of SDG 11, governments, development partners, and urban institutions need to treat remote sensing as an important component of urban governance. With cities expanding rapidly and unevenly, satellite-derived insights offer consistent and scalable ways to understand these dynamics (Seto et al., 2012; Angel et al., 2011), providing a transparent basis for prioritising deprived neighbourhoods, targeting infrastructure investment (Andersson & Crnojevic, 2025) and structuring urban renewal programmes without dependence on costly and time-consuming field surveys.

Embedding remote sensing into decision-making can enable countries to steer growth away from unmanaged sprawl, anticipate material demand, and support circular-economy and decarbonization pathways (Pauliuk & Müller, 2014; O'Brien et al., 2020). Development partners should support capacity building so that vulnerable regions can use remote sensing effectively.

The tools exist; the data is increasingly available. Remote sensing hence makes the built environment observable, revealing where growth is happening, what form it takes and what it implies for sustainability, resilience and equity (Ma et al., 2024; Sun et al., 2025) making it paramount for evidence-based implementation of SDG 11.

References

Andersson, M., & Crnojevic, V. (2025). *Space applications and global sustainable development.* Science-Policy Brief for the UN Multistakeholder Forum on Science, Technology, and Innovation for the SDGs.

Angel, S., Parent, J., Civco, D., & Blei, A. (2011). *Making room for a planet of cities.* Lincoln Institute of Land Policy.

European Commission, Joint Research Centre. (2024). *GHS-OBAT: Global Human Settlement – Open Buildings Attribute Table.* JRC Publications Repository.

Georgiou, A., Karathanassi, V., & Stathopoulou, M. (2022). Remote sensing for rapid disaster damage assessment: A review. *ISPRS Journal of Photogrammetry and Remote Sensing, 183*, 209–228.

Koks, E. E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousdoukas, M., Fraser, S., … Hallegatte, S. (2019). A global multi-hazard risk analysis of road and railway infrastructure assets. *Nature Communications, 10*, 2677.

Kuffer, M., Pfeffer, K., & Sliuzas, R. (2016). Slums from space—15 years of slum mapping using remote sensing. *Remote Sensing, 8*(6), 455.

Li, X., Zhou, Y., Gong, P., Seto, K. C., & Clinton, N. (2020). Developing a global 3D urban structure map from spaceborne SAR data. *Remote Sensing of Environment, 245*, 111859.

Ma, X., Zheng, G., Xu, C., Moskal, L. M., Gong, P., Guo, Q., … Zhou, Y. (2024). A global product of 150-m urban building height based on spaceborne lidar. *Scientific Data, 11*, 1387.

O'Brien, M., Weidema, B., & Schmidt, J. (2020). Modelling global construction material flows and embodied carbon. *Nature Sustainability, 3*(7), 563–571.

Pauliuk, S., & Müller, D. B. (2014). The role of material stock dynamics for sustainable resource management. *Proceedings of the National Academy of Sciences, 111*(15), 5607–5612.

Pesaresi, M., Ehrlich, D., Ferri, S., Florczyk, A., Freire, S., Halkia, M., … Syrris, V. (2016). Operating procedure to produce the

Global Human Settlement Layer from Landsat data. *Publications Office of the European Union.*

Rajaratnam, D., Stewart, R. A., Liu, T., & Vieira, A. S. (2023). Building stock mining for a circular economy: A systematic review of application of GIS and remote sensing. *Resources, Conservation & Recycling Advances, 18*, 200144.

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences, 109*(40), 16083–16088.

Stokes, E. C., Hooper, A., & Bekaert, D. (2021). Estimating building heights from Sentinel-1 SAR interferometry. *Scientific Reports, 11*, 12345.

Sun, K., Li, Q., Liu, Q., Song, J., Dai, M., Qian, X., … Liu, G. (2025). Urban fabric decoded: High-precision building material identification via deep learning and remote sensing. *Environmental Science and Ecotechnology, 24*, 100538.

Taubenböck, H., & Kraff, N. J. (2014). The morphology of the urban landscape. *Remote Sensing of Environment, 142*, 112–132.

UN-Habitat. (2021). *Indicator 11.3.1 training module: Land use efficiency.* Nairobi: UN-Habitat.

UN-Habitat. (n.d.). *SDG Goal 11 Monitoring Framework: Definitions, metadata, and guidance for national and local governments.*

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development (A/RES/70/1).*