Global Development Assistance

Urban Sustainability

June 2022

powered by esa in partnership with ADB

Lead

GAF AG

an e-GEOS (ASI / Telespazio) Company

Consortium partners

DLR

TRE ALTAMIRA

gisat

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

Caribou Space

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Contents

What does ESA's Global Development Assistance (GDA) activity on Urban Sustainability do?

The European Space Agency's Global Development Assistance (GDA) programme is a global partnership to mainstream the use of Earth Observation (EO) into development operations, implemented in cooperation with major International Financial Institutions (IFIs).

To foster adoption and accelerate impact, GDA focuses on targeted Agile EO Information Development (GDA AID) applied to thematic priority sectors.

For further context please see: https://gda.esa.int/thematic-areas/

The GDA AID Urban Sustainability activity (herein referred to as GDA Urban) has been established as part of this programmatic cooperation with IFIs and partners specifically with the World Bank (WB), the Asian Development Bank (ADB), and the African Development Bank (AfDB).

GDA Urban will provide EO Information in response to requirements identified in the urban domain by IFIs and their Client Country governments in developing countries. The activity will assist IFI teams and local authorities in making better locational and planning decisions e.g., with regards to policies, regulations, or investments.

This booklet provides a summary of GDA Urban. It also presents examples of combining different EO Information to visualise urban phenomena.

For further information please see: https://gda.esa.int/thematic-area/urban-sustainability

What themes of Urban Sustainability are included?

GDA Urban will focus on four major urban themes as per Figure 1.

FIGURE 1: Urban Themes

Urban planning & land administration

Data on land use/land cover and urban growth underpin master planning to guide development and improve access to services for all. Accurate and fair property valuation and taxation requires reliable building footprints & heights.

Urban transport

Sustainable urban transport, including road, rail, airports, and ports, has a key part to play in fostering inclusive growth, expanding access to essential services, and mitigating impacts of climate change.

Urban environment & health

Monitoring and minimising urban environmental issues such as habitat loss, air pollution, urban heat islands, and lack of green spaces, ensures liveability & public health.

Urban climate resilience

Extreme weather events related to climate change cause frequent flood damage, landslides and coastal erosion impacting urban areas. Resilient cities accurately map these risks, plan for them, and minimise exposure to populations and infrastructure.

Who runs GDA Urban?

The activity is implemented by a consortium of six European companies leading in the fields of EO, remote sensing, Geographic Information Systems (GIS), urban modelling and the integration of technology into international development contexts.

The consortium is led by GAF AG.

The members are:
GAF AG (DE),
TRE-Altamira (ES),
AIT (AT),
GISAT (CZ),
DLR (DE),
Caribou Space (UK).

Priorities for GDA Urban

The consortium, in close conversation with WB, ADB and AfDB, collects the operational needs of IFI projects and programmes to identify possible innovative applications to be rolled out in **8–12 urban areas**.

These applications must:

1. **Be demand-driven:** The need for a particular service or product has been expressed by an IFI team or preferably several teams or departments with an interest for the same EO Information.
2. **Be innovative:** The request corresponds to innovative services or products that require customisation and therefore are not already and readily available through commercial entities.
3. **Have potential for wider uptake:** The service or product requested has significant potential for operational uptake and adoption in client countries.

Use case examples

Quantifying the exposure of assets and populations to flood hazards

Land use/land cover

What it is: A status of land use/land cover (LULC) on the level of individual cities, metropolitan areas, or agglomerations. Typical land cover classes follow established nomenclatures at varying levels of detail. LULC maps are a foundational input layer to other base products and applications. Multi-temporal LULCs can provide valuable insights into land use changes over time.

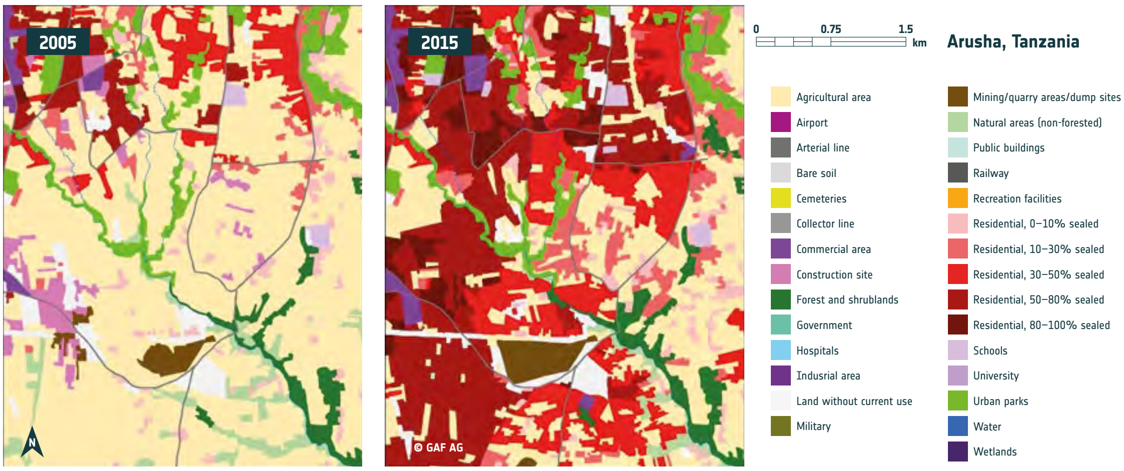
Spatial resolution: Up to 0.5m, though lower resolutions of 10–30m are often more than sufficient for most larger scale applications.

Thematic accuracy: Above 80%, depending on the quality of the EO data and landscape characteristics to be mapped (amount and type of thematic classes).

Minimum Mapping Unit: 500m²

What to watch out for: Many LULCs cover 15, 20 or even 30 classes, and, when turned into a map product, often represent these classes through hard-to-distinguish colours. Humans are usually only able to differentiate and attribute 10 colours or less. If you are overwhelmed by an LULC, especially at the scale of an entire city, be aware that most city-scale LULCs are not intended as insight-providing products by themselves, but instead feed into further products and analyses, often at larger scales.

FIGURE 2: Land Use/Land Cover for Arusha, Tanzania, in 2005 and 2015 © GAF AG



2D building and building block footprints

What it is: Artificial Intelligence (AI)-derived building or building block outlines in vector format.

Spatial resolution: 0.5m

Thematic accuracy: ~70% to 80% if using a pre-trained model not adjusted to a specific or new city/region, otherwise 80% and above can be achieved if adjusting the model to the specific area of interest using manually derived training data (e.g. OpenStreetMap, local authority data). Accuracies should increase further using 0.3m input imagery.

Minimum Mapping Unit: Features should be at least 5×5m in size.

What to watch out for: AI has dramatically reduced the costs of identifying building footprints and heights, though their accuracy prior to post-processing depends on the quality of the underlying Very High Resolution (VHR) imagery (spatial resolution, haziness, shadows, cloud cover etc.) and the quality of training data. Manual correction of detected features may then still be necessary and increase costs.

FIGURE 3: AI-derived 2D Building Footprints (R) over Maxar DynamicMosaic (L) in Nigeria © GAF AG

3D building footprints and digital surface models

What it is: A Very High Resolution (VHR) Digital Surface Model (DSM), covering terrain relief as well as vegetation and man-made features such as buildings and infrastructure. Understanding the impact of the third dimension on the behaviour of floods and landslides as well as the vertical expansion of cities is made possible through satellite (multi-) stereo imagery—multiple images of the same area taken from different perspectives.

Spatial resolution (horizontal): 0.3–0.5m

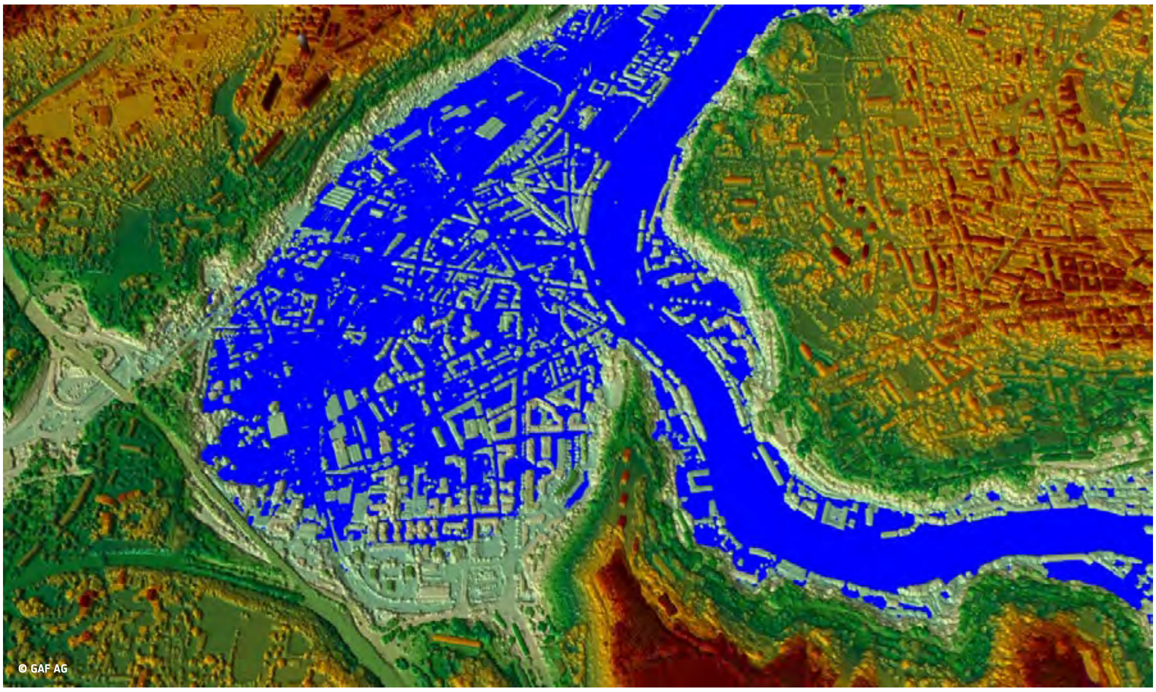
Thematic accuracy (horizontal): Similar to 2D building footprints and building blocks.

Absolute vertical accuracy: < 3m (LE90)

Relative vertical accuracy: < 1m

What to watch out for: For 3D building footprints, the accuracy of the vertical dimension depends on the quality of the DSM and the Digital Terrain Model (DTM), meaning the terrain relief without surface features. Especially in densely built-up areas over undulating relief it can be difficult to estimate the correct base height.

FIGURE 4: 50 cm Multi-Stereo DSM of Lyon, France © 2018, GAF AG, includes EUSI / Maxar material



Population distribution and density

What it is: A geographically referenced raster grid with each pixel value providing an estimate of the number of people residing within that particular grid cell. This information can then be further aggregated into coarser spatial units such as building blocks or administrative areas.

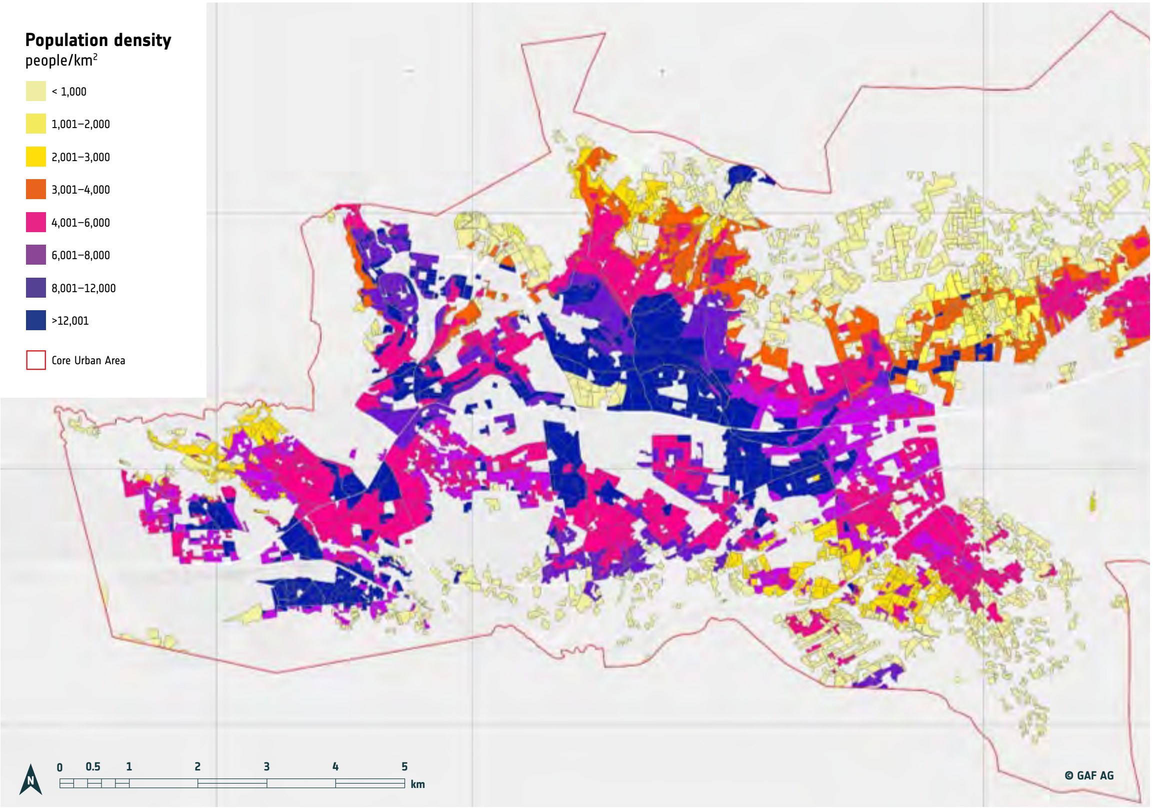
Spatial resolution: 10–30m are more than sufficient for most applications.

Thematic accuracy: 80% and higher

Minimum Mapping Unit: 500m²

What to watch out for: The reliability of the population distribution estimates depends on the availability and reliability of the coarse-scale census data which are then disaggregated across spatial units that are much smaller than the original census districts.

FIGURE 5: Population Density for Mbeya, Tanzania, in 2015 © GAF AG



Flood extent and frequency

What it is: The extent of historic flood events. The extent and duration of flood events can be mapped using multiple Synthetic Aperture Radar (SAR) acquisitions. A Water Frequency Map can further quantify how many times (in %) a pixel has been classified as water when examining longer time spans. This can help authorities better predict the risk exposure of fixed assets and people.

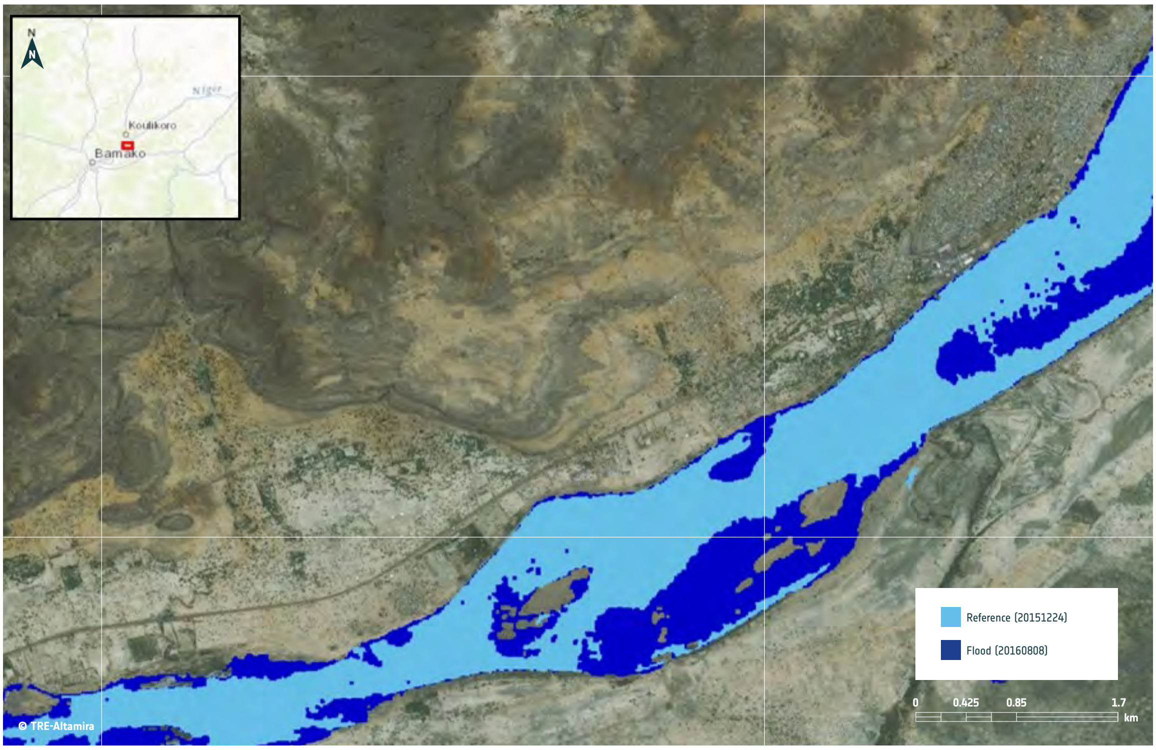
Spatial resolution: Equivalent to the native resolution of the satellite system used – e.g., 5m × 20m (Sentinel-1, IW) or 3m × 3m (TerraSAR-X, SM).

Thematic accuracy: >85%

Minimum Mapping Unit: 5×5 pixels, Sentinel-1 equivalent area ~ 2500 m² and TerraSAR-X ~ 225 m²

What to watch out for: In order to improve the quality of the water extent layers, optical imagery such as Sentinel-2 data can be employed.

FIGURE 6: Mapping the Extent of the August 2016 Flood in Bamako, Mali © TRE-Altamira



Combining LULC, population distribution estimates, building footprints, heights and uses with risk layers such as a water frequency map as well as other non-EO data such as asset estimates in monetary terms, makes it possible to turn abstract concepts such as risk levels into potentially more convincing monetary figures of economic value at risk.

Modelling urban growth based on attractors and socio-economic data

Urban extent

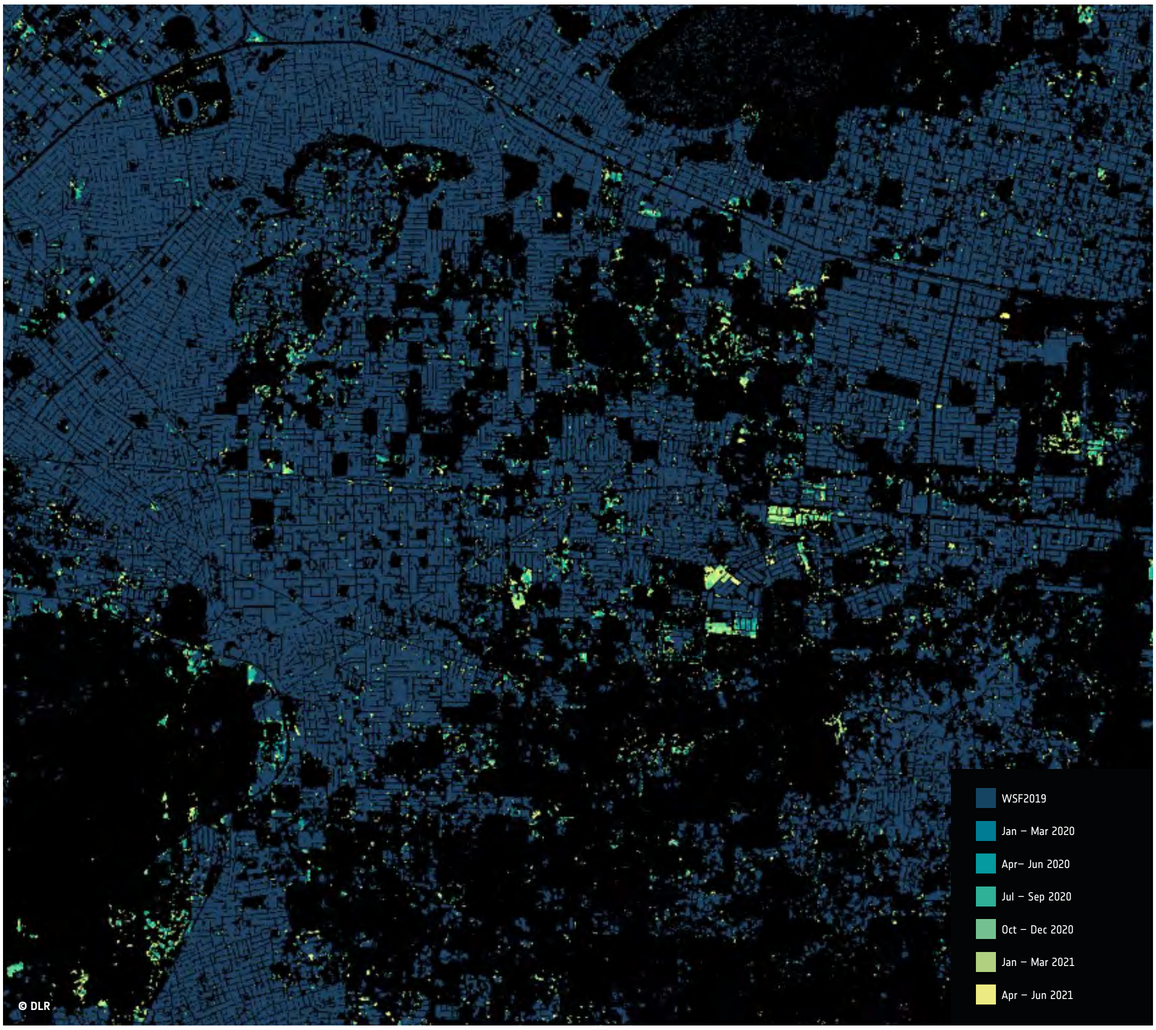
What it is: A binary layer indicating urban and non-urban areas. Increasingly, both low-frequency (e.g., decadal) as well as high-frequency monitoring of urban extent are useful tools to understand the historical, and to a lesser degree, the future horizontal growth of cities; such information can then be used for planning purposes.

Spatial resolution: 10m (e.g., World Settlement Footprint 2019) to 30m (e.g., WSF Evolution).

Thematic accuracy: 85% or higher

Minimum Mapping Unit: 500m²

FIGURE 7: High Frequency Settlement Monitoring for Bamako, Mali © DLR



Extent and type of informal settlements

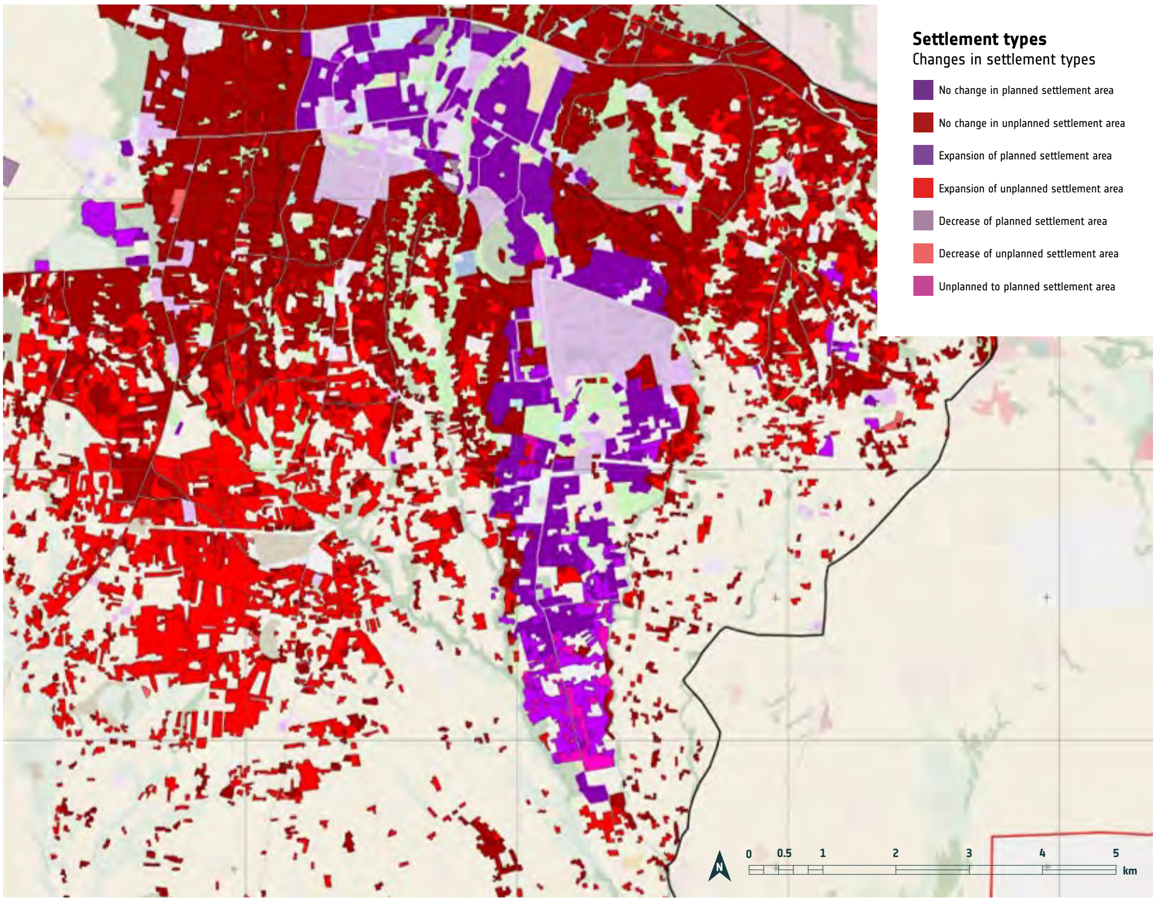
What it is: A map product outlining the extent and key characteristics of informal settlements. Whether settlements are established or new developments as well as spatial metrics such as compactness, patch size and density of buildings provide information on the type of informal settlement.

Spatial resolution: 0.5–1m

Thematic accuracy: Above 80%

Minimum Mapping Unit: 500m²

FIGURE 8: The Change in Settlement Types in Arusha, Tanzania, between 2005 and 2015 © GAF AG



Use Case Examples | Global Development Assistance: Urban Sustainability

Open and green areas

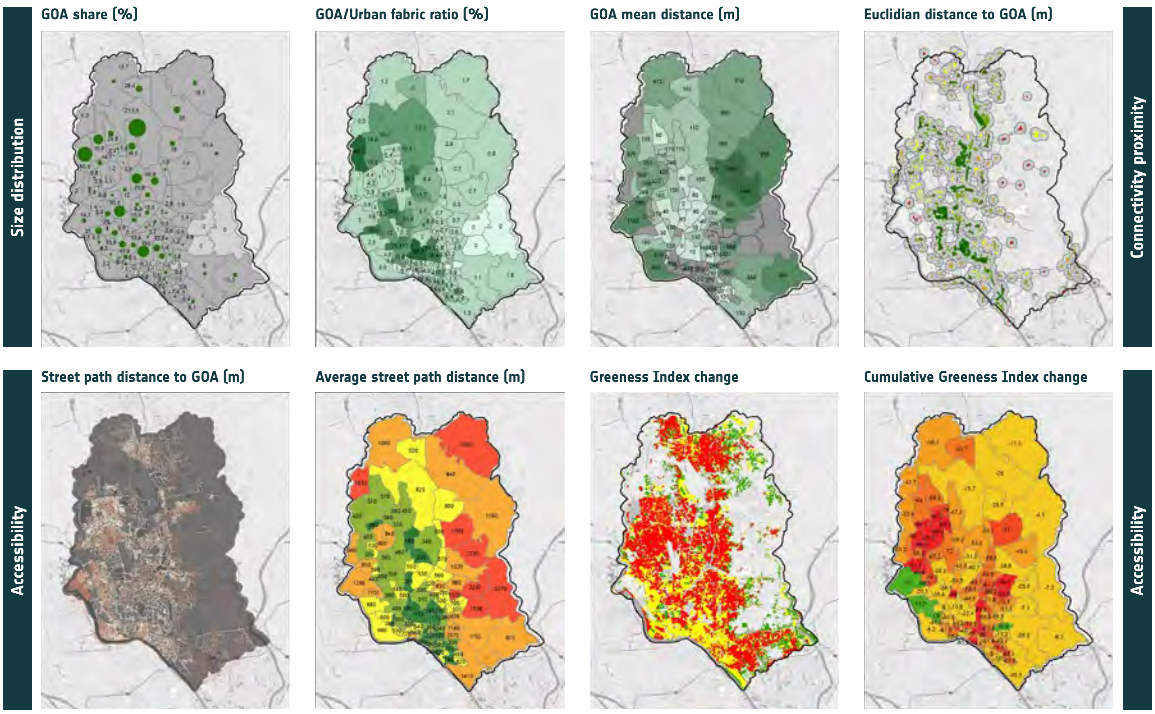
What it is: The location and type of open or green areas. Non-vegetated open spaces can also be included. Derived statistics on their respective distribution, connectivity, accessibility, and evolution over time can be calculated to identify deprived areas and prioritise investments. Green areas as part of nature-based solutions (NBS) are important for cities to achieve climate resilience and increase liveability.

Spatial resolution: Up to 5m

Thematic accuracy: 85% or higher

Minimum Mapping Unit: 100m²

FIGURE 9: Various Indicators for Open and Green Areas in Dhaka, Bangladesh © GISAT



Past trends are important, but not the only indicator for where urban growth will occur in the future. Factors such as topography, natural hazards, infrastructure investments, the growth and location decisions of different socio-economic groups as well as the perceived “attractiveness” of neighbourhoods can have a major impact on where growth will occur. Advanced modelling platforms iteratively and interactively allow local stakeholders to input EO and non-EO data and weight these push and pull factors' level of importance depending on their local context.

Locating road infrastructure exposed to ground motion

Transport infrastructure

What it is: A vector product including rail and road infrastructure. A standard hierarchy differentiates between highways, primary, secondary, tertiary, and local roads as well as unpaved tracks. This product is essential for the LULC product as well as for assessing the accessibility of amenities, social infrastructure, and many other urban assets.

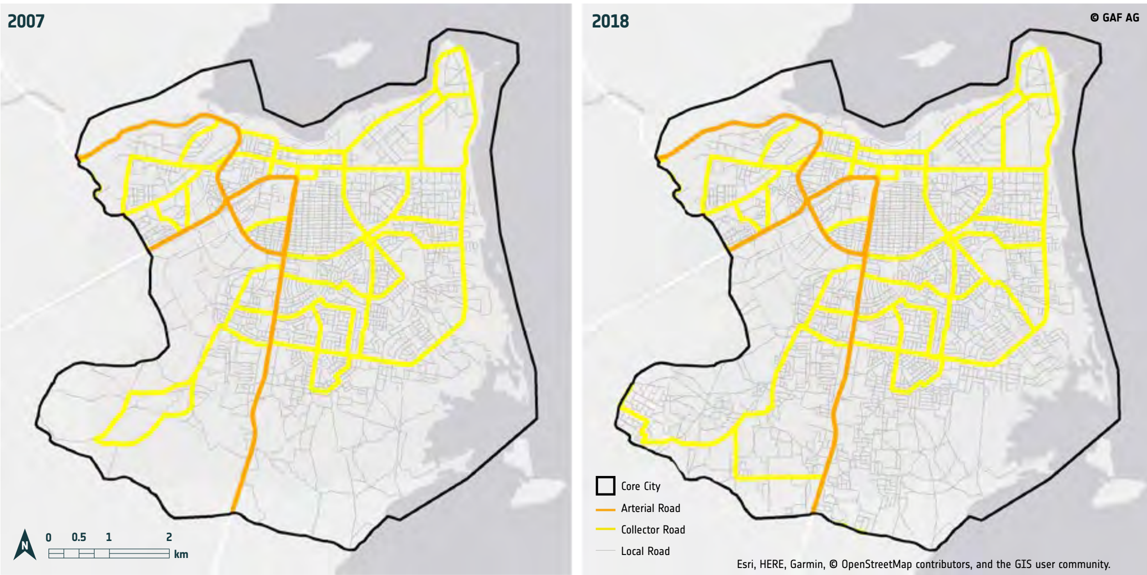
Thematic accuracy: > 80%

Spatial resolution: Up to 0.5m

Minimum Mapping Unit (manual acquisition): Length – 50m, Width – 5m

What to watch out for: AI-derived road segments can be used as an interim product to reduce the manual effort for completing a road network. Based on currently available training data, paved and unpaved roads can be distinguished through an automated approach.

FIGURE 10: Changes in the Transport Network in Tanga, Tanzania, between 2007 and 2018 © GAF AG



Ground displacement

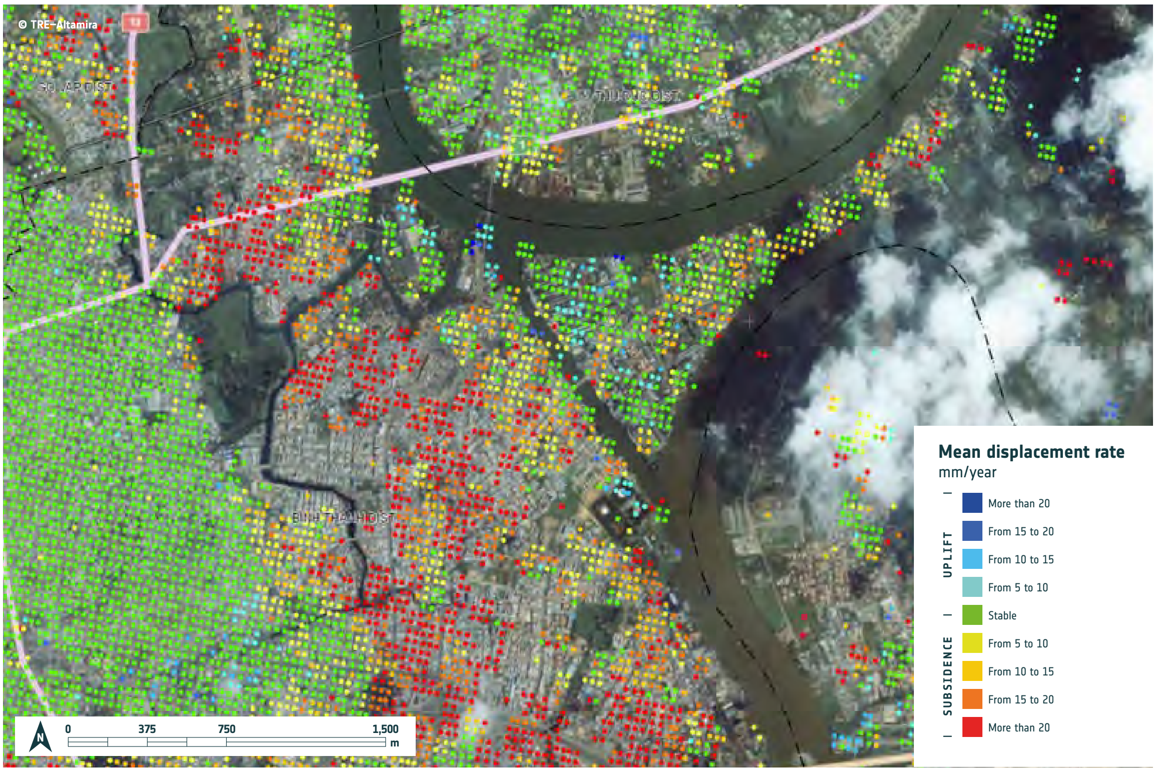
What it is: A map product where each coloured dot (e.g., in the map below) represents an average displacement rate (subsidence or uplift) in mm/year over a monitoring period. Displacement is triggered by tectonic activity, urban development leading to an increased load and/or ground water extraction. Ground displacement represents a grave threat to the built environment and therefore to people.

Spatial resolution: For 1-D displacement (away from or towards the satellite's Lineof Sight or LOS), equivalent to the native resolution of the satellite system used – e.g., 5m × 20m (Sentinel-1, IW) or 3m × 3m (TerraSAR-X, SM).

Minimum Mapping Unit: ~100 m2 (Sentinel-1) or ~10 m2 (TerraSAR-X).

What to watch out for: TRE-Altamira's SqueeSAR algorithm can measure displacement with millimeter precision. The precision increases with the number and frequency of processed images, the quality of the images, the length of the period of analysis, the coherence of the signal (i.e., the absence of vegetation or surface disturbances) and the density of points identified. 2-D measurements (vertical or east-west displacement) are generally easier to interpret than 1-D (LOS-based) measurements, but they have a lower spatial resolution. For a detailed analysis of localised features, it may be beneficial to use the full resolution LOS results.

FIGURE 11: Mean Displacement rate between 2005 and 2009 in Ho Chi Minh City, Vietnam © TRE-Altamira



Identifying which buildings or road segments are exposed to either subsidence or uplift is crucial for city authorities to take remedial measures. It is also an important consideration in zoning certain areas for any, or only particular types of development.

Glossary

- **Spatial resolution** – Spatial resolution is the degree to which an image can differentiate spatial variation of terrain features. It is often specified as ground resolution cell size in meters. A "higher" spatial resolution implies a lower ground resolution cell size. In our examples, we reference either the highest currently possible resolution or the highest resolution recommended for most analytical applications in the urban domain.
- **Minimum Mapping Unit (MMU)** – The MMU is the smallest size that determines whether a feature is captured from a remotely sensed image.
- **LE90** – LE90 is the 90th percentile linear error, meaning that a minimum of 90 percent of vertical errors fall within the stated value.
- **Thematic accuracy** – A "thematic accuracy of X%" means that X% of the land cover classes identified through EO have been identified correctly. This is done by comparing the land cover of randomly placed sample points against even higher resolution EO data, secondary or in-situ data, or by conducting a plausibility check.
- **Absolute vertical accuracy** – Absolute vertical accuracy accounts for all effects of systematic and random errors, and relates the modeled elevation to the true elevation with respect to an established geo-referenced vertical datum (e.g. the mean sea level).
- **Relative vertical accuracy** – Relative vertical accuracy is the elevation difference between two points measured on the digital elevation model vis-à-vis the elevation difference between the same two points on the reference surface.

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Contact us via gda@esa.int