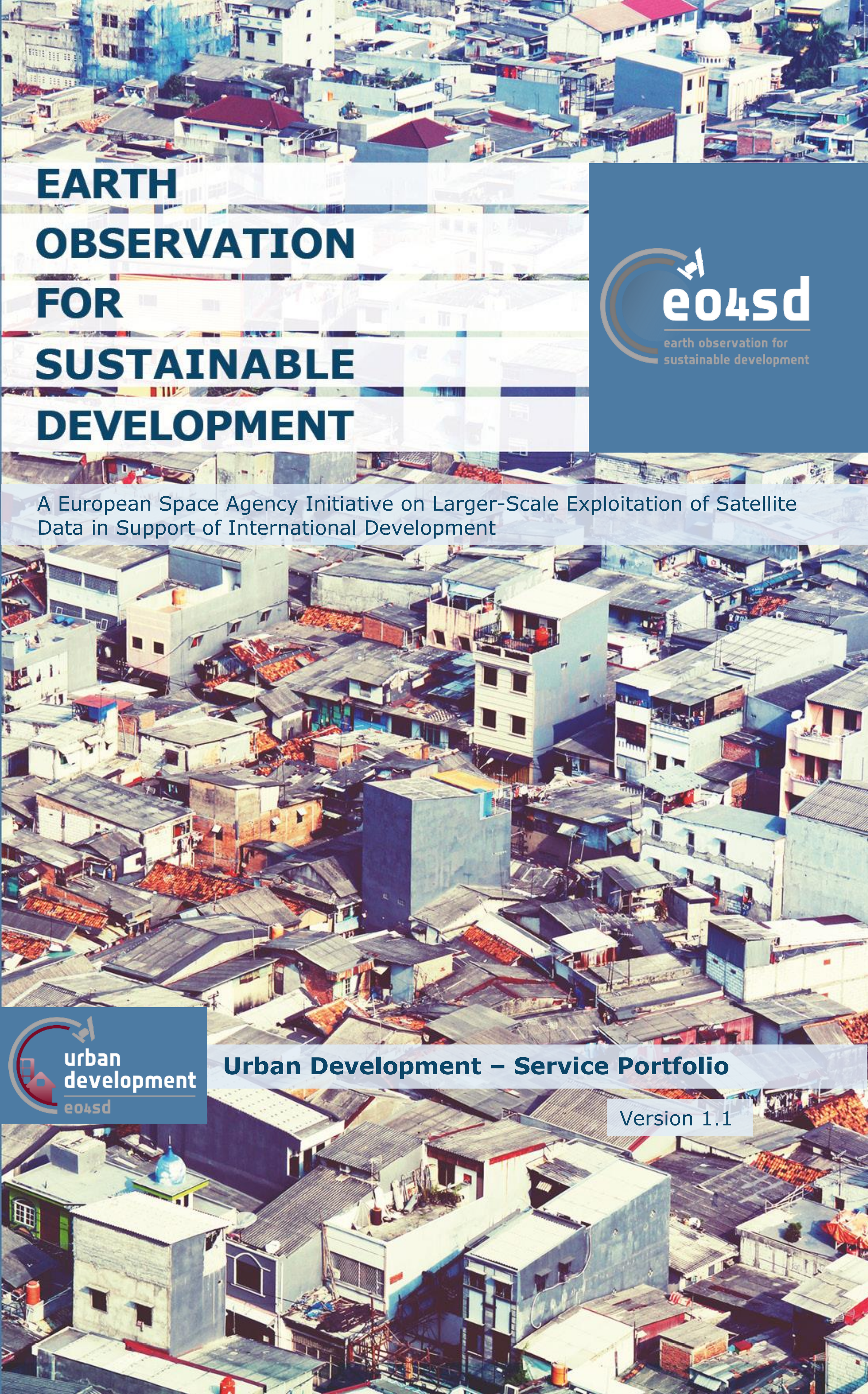
EO4SD

EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

eo4sd
earth observation for sustainable development

A European Space Agency Initiative on Larger-Scale Exploitation of Satellite Data in Support of International Development



urban development
eo4sd

Urban Development – Service Portfolio

Version 1.1

INTRODUCTION

Background

The challenges faced by governments to manage the staggering growth of urban areas worldwide are multi-faceted as they have to cover certain basic needs of the population in terms of infrastructure, access to clean water, electricity, sanitation and avoid urban poverty, which has consequences on the overall development of the country.

Satellite Earth Observation (EO) technology has major potential to inform and facilitate international development work in a globally consistent manner. It has also become a powerful tool for the inventory and analyses of urban areas.

The data has the unique ability to allow the evaluation of past and present spatial features and structures on the ground with frequent, detailed and basically global coverage, allowing comprehensive analyses of the development and trends of spatial urban patterns.

EO4SD Initiative

Since 2008 the European Space Agency (ESA) has worked closely together with the International Financing Institutions (IFIs) and their client countries to harness the benefits of EO in their operations and resources management.

EO4SD – Earth Observation for Sustainable Development - is a new ESA initiative, which aims to achieve an increase in the uptake of satellite based information in the IFIs regional and global programmes. It will follow a systematic user-driven approach in order to meet longer-term, strategic geospatial information needs in the individual developing countries, as well as international and regional development organisations.

Although a wide range of issues have been identified where EO can have an impact, the EO4SD initiative will begin by addressing three top-priority thematic areas:

1. Urban Development,
2. Agriculture and Rural Development, and
3. Water Resources Management.

The activities will be implemented in the 2016-2018 timeframe, with Phase I (2016-2017) dedicated to the stakeholders' engagement and requirements consolidation, and Phase II (2017-2018) focusing on EO information production, delivery and capacity building with the users to ensure that the information brings benefit to operational activities.

The current product portfolio is for the Urban Development Service Cluster.

Policy Framework and Urban Sustainability Indicators

A main objective of the EO4SD-Urban Product Portfolio is to support the reporting requirements of Urban Development Policies and Strategies. One of the most important policy frameworks that countries are trying to implement is the UN Sustainable Development Goals (SDG). Seventeen SDGs were developed with a focus on "ending extreme poverty; fighting inequality & injustice; and addressing climate change," by 2030. To achieve the 17 goals there are 169 targets and for each Target, Indicators will be used to assess levels of achievement of the countries.

The SDG Goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable" is specifically dedicated to Sustainable Urban Development.

A list of Urban Sustainability Indicators specific to the SDG Goal 11, have been defined in March 2016 by the UN and are described in the UN-Habitat "SDG Goal 11 Monitoring Framework Report (UN, 2016a)." The following SDG Goal 11 Indicators can be fully or partly assessed using the EO4SD-Urban products.

Additional Urban Sustainability Indicators have been developed by international and regional organisations, such as the United Nations (2007), the UN-Habitat (2004), the World Bank (2008), the Asia Development Bank (2001), and the European Commission (2003). Urban Sustainability Indicators directly measurable by the offered products are:

SDG Goals 11 Indicators

- Proportion of Urban Population Living in Slums, Informal Settlements
- Ratio of Land Consumption Rate to Population Growth
- Proportion of Population that have convenient access to Public Transport
- …

City Structures

- Number of Inhabitants per km^2 (Shen et al., 2011)
- Floor Area per Person (ADB, 2001)
- Urban Population Growth (UN-Habitat, 2004)

Transportation

- Km of Transportation System per 100,000 Population (WB, 2008)
- Expenditure on Local Infrastructure (ADB, 2001)

Shelter

- Percentage of City Population living in Slums (UN, 2003; 2007; WB, 2008)
- Area Size of Informal Settlements as a Percent of City Area and Population (WB, 2008)

Urban Planning

- Planned Settlements (UN-Habitat, 2004)
- Green Areas per 100,000 Population (WB, 2008)
- Square Meters of Public Recreation Facility Space per Capita (WB, 2008)

Natural Hazards

- Percentage of Population Living/Housing in Hazard Prone Areas (UN-Habitat, 2004; WB, 2008)
- Number and Extent of Disasters over past 10 Years (ADB, 2001)

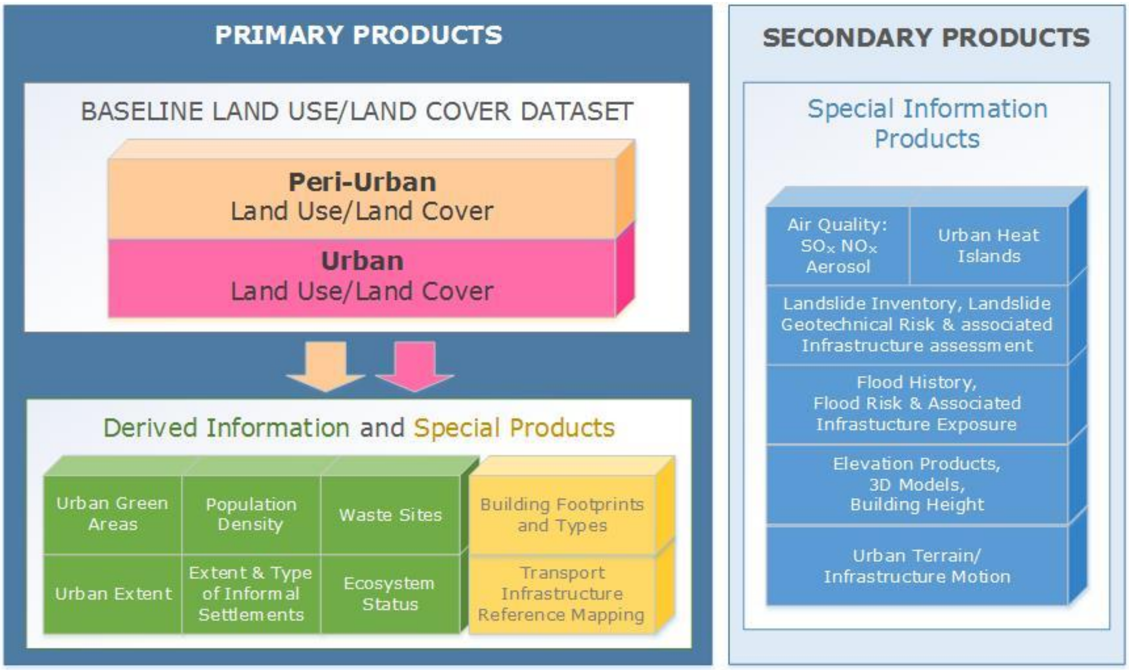
All the products described in the current Portfolio are potentially useful for the derivation of the above Urban Sustainability Indicators.

EO Product Portfolio Overview for Urban Development

Based on the current state-of-the-art of satellite remote sensing and initial discussions with stakeholders, the current service portfolio of the Urban Development Service Cluster outlines the preliminary composition of the information services/products which can be provided. These can be grouped in two categories, primary and secondary.

The current project will focus on the primary products in terms of coverage and effort (indicatively 80%). The secondary products, can be offered when specific cases require such data, or as general awareness-raising demonstrators with limited coverage. The provision of well-established, off-the-shelf (non-ESA) commercial products (e.g. elevation data) as stand-alone products will be avoided. Most flood and terrain motion services have high operational maturity and are planned to form the basis of a dedicated EO4SD subproject on Risk Management.

Efforts will be made to assist the users with higher-level analytical products using innovative geo-statistical methods, addressing (especially for the primary products) e.g. fragmentation, connectivity and access, and environmental impact.



The temporal evolution or the monitoring over a time period of the parameters in the products is equally feasible. However, the spatial resolution and quality of the historical input imagery can vary and will impact the overall accuracy of the results.

Each product is described in terms of contextual urban planning issues and examples of potential utility in different development programmes are provided.

The Consortium implementing the Urban Development Service Cluster has well established experience in providing quality assured operational services in the urban domain to users in both developing and developed countries. Additionally, the Consortium has related experience to provide capacity building.

Urban and Peri-Urban Land Use/Land Cover

Content and Use

As urban areas are often dependent on the resources available in the peri-urban areas (which are often transition zones to rural areas), the land use planning and management of these areas is an important aspect of sustainable urbanisation.

The product Urban and Peri-Urban Land Use/Land Cover maps and related change maps represent a detailed status of spatial-temporal land use/land cover patterns in these areas on the level of individual cities or larger administrative or functional areas (i.e. metropolitan areas, agglomeration). Typical land cover classes used in the classification follow the established nomenclatures such as continuous and discontinuous urban fabrics, industrial, commercial and public units, road and rail networks, port areas, airports, green urban areas, agricultural land, forests, sport and leisure facilities. The map classes can be adapted to the specific urban areas and user requirements.

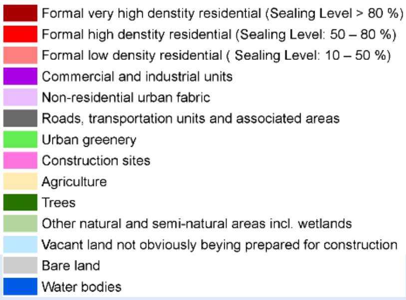
The product serves as a starting point for a range of urban spatial statistical analyses. It can be further used to understand how development trends are impacting specific locations that are related to a city's unique selling point (ADB, 2016).

Resolution, Availability and Frequency

The spatial resolution of most urban mapping products can be up to 0.5m, depending on the input imagery resolution. Construction classes can be estimated from block level, resulting in 1:5,000/ 1:10,000 scale maps to lesser detailed maps, resulting in 1:100,000 scale maps.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

The update frequency of the product is usually once every one to five years. It is limited only by the availability of the satellite data.



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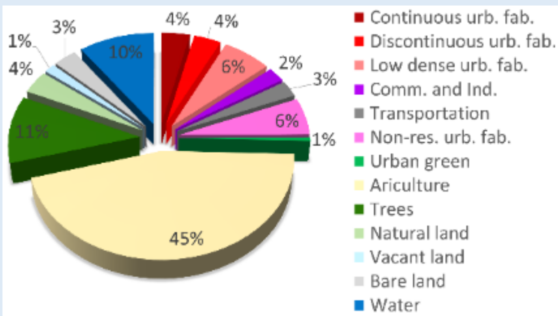


(2)

(1) 3D view of a Land Use/Cover Map of Mandalay, Myanmar in 2002 (above) and in 2015 (below). The maps are based on QuickBird (above) and on PLEIADES-1b (below) satellite imagery. (GISAT)

(2) The pie chart visualises the area of the urban and peri-urban land use classes of Mandalay, Myanmar in 2015. (GISAT)

Reliability

The geometric accuracy is usually comparable to the spatial resolution of the input data, normally extending to a few meters.

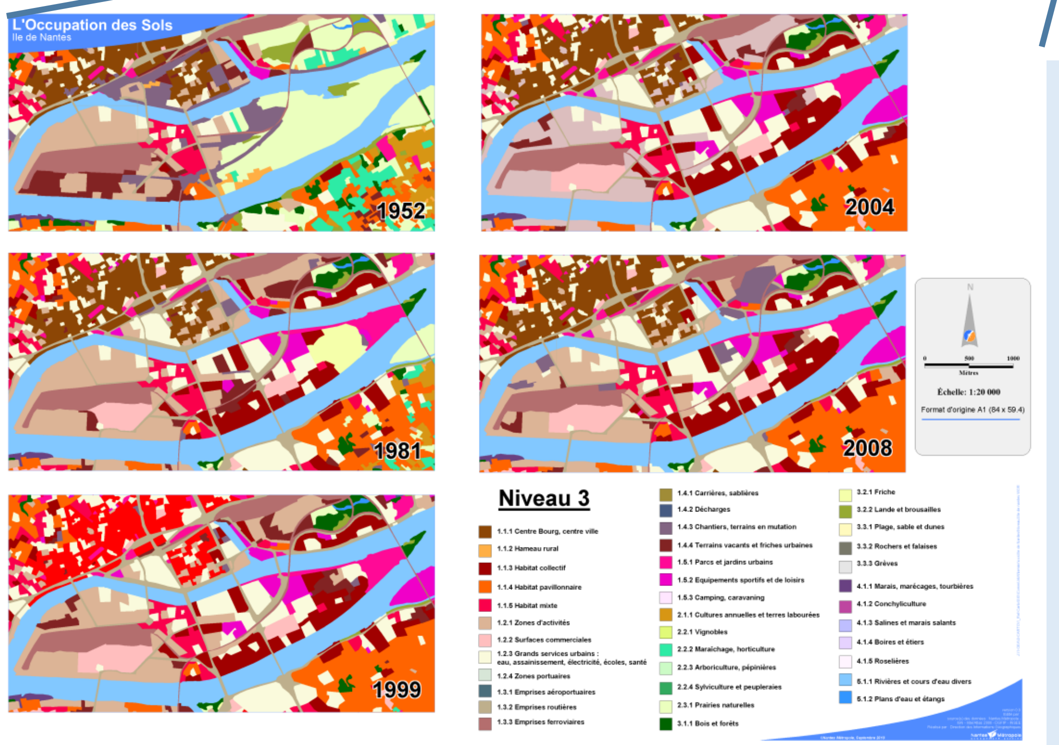
The thematic (classification) accuracy is higher than 80%, depending on the quality of the EO data and landscape characteristics

Benefits

Land use/land cover maps derived with Earth Observation data allow the evaluation of existing spatial structures in a homogenous, comparable and up-to-data manner. Satellite remote sensing offers a tremendous advantage over historical maps or aerial photos as it provides recurrent and consistent observations over a large geographical areas, reveals explicit patterns of land cover and land use and presents a synoptic view of the landscape (Schneider & Woodcock, 2008).

The high temporal resolution connected with low production costs allow the comparison of the capacity of specific locations relative to the projected demand arising from growth in populations and economic activities (World Bank, 2010). With such information urban planners can easily capture infrastructure bottlenecks and spatial structures important to be improved and prioritize activities and investments.

(3) Detailed urban and peri-urban land use / land cover over a 56 year monitoring period illustrating the urban renewal phenomenon in Nantes, France. (SIRS)



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Content and Use

Uncontrolled urban sprawl has environmental, social and economic impacts on a city and country. To reliably delineate the urban growth which has occurred in the last decades, modelling of the temporal evolution of urbanization can be undertaken. The results of this modeling can be the basis for better estimating future trends and implementing suitable urban planning strategies.

Many developing countries often have no digital records of urban extent and the maps are still mostly generated via costly field surveys. Both the rate and extent of urban sprawl can be provided with Earth Observation data.

Urban sprawl maps which include the classes urban and non-urban, provide the information needed for urban sprawl assessment. The maps also emphasize spatial patterns and intensity of changes which assist in relevant policy development for management of urban expansion in an effective, efficient, equitable and sustainable manner for the selected city.

Resolution, Availability and Frequency

The spatial resolution of the product can be produced between 0.5 and 100m resulting in scales between 1:5,000/ 1:10,000 to 1:100,000. This very high to high resolution data allows the analyses of spatial growth at local, regional and global levels.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore can range between a few days and weeks.

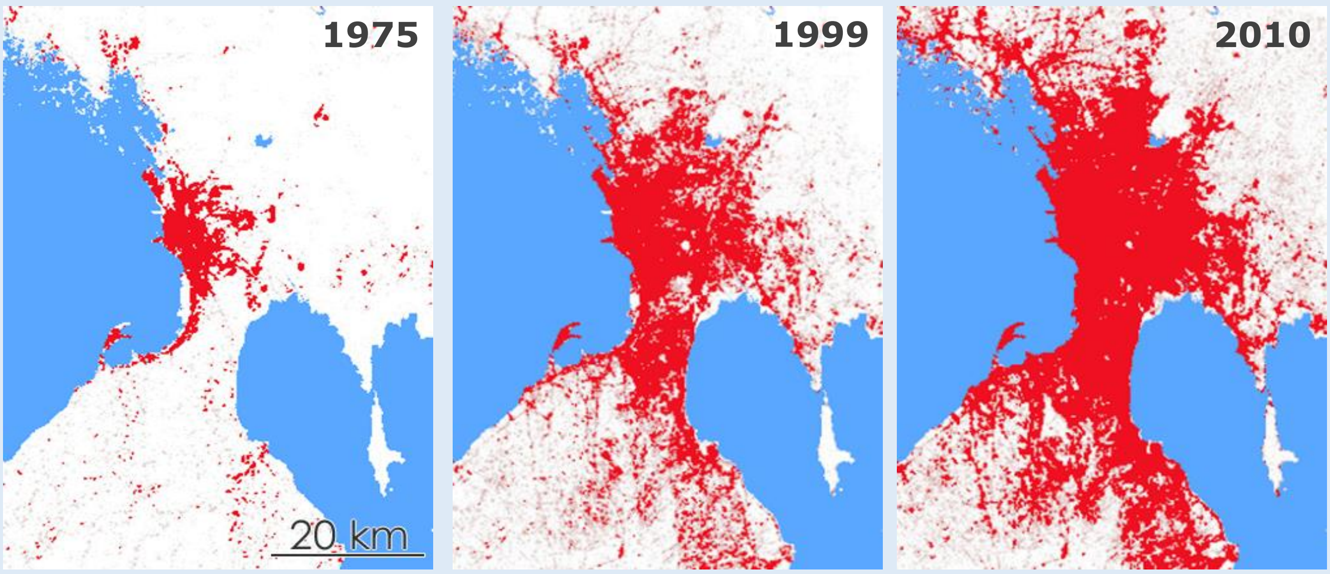
The update frequency of the product is usually once every one to five years and is customizable to dynamics of city development.

Reliability

The geometric accuracy is usually comparable to the spatial resolution of the input data, normally ranging between a few meters.

The thematic (classification) accuracy is up to 90%, depending on resolution and settlement character.

(1) The dramatic extension of the urban extent (red) of Manila, Philippines over the last 35 years based on Landsat 4/5/7 satellite imagery. (DLR)



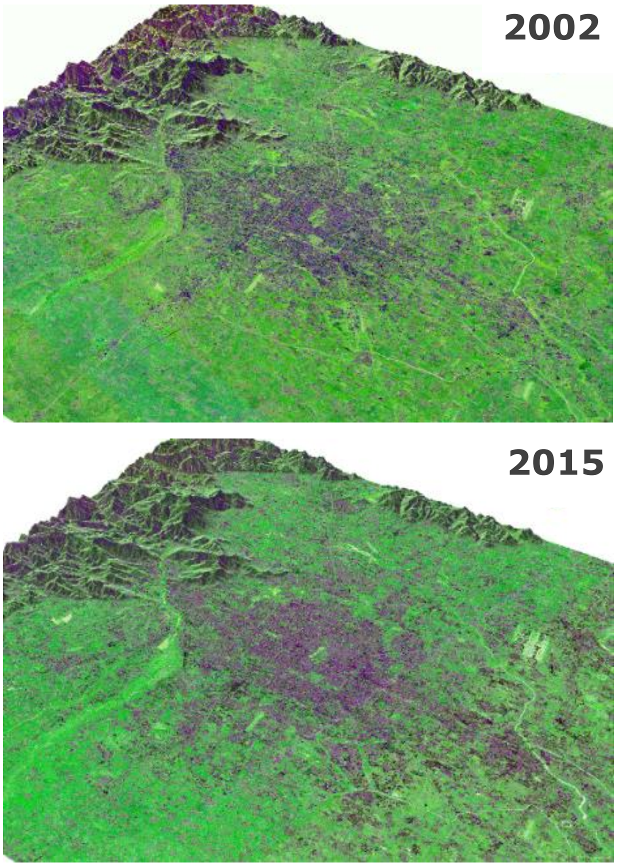
(1)

Benefits

Urban extent maps derived with EO data are independent, up-to-date and available globally. The product is also reproducible and thus harmonized, consistent and can be used in comparative analysis between cities. The products/services offer highly valuable and cost efficient methods for assessing urban extent.
Furthermore, the product serves as starting point for the more detailed land use/land cover maps.

(2) The expansion of Beijing, China is identified from a 3D color composite of Sentinel-1A satellite imagery based on multi-temporal indexes at 10m spatial resolution in 2002 (above) and in 2015 (below). (DLR)

(3) The Pearl River Delta, China is one of the most populated areas in the world with recent growth between 2002 and 2015 linked to its economic development. Above: Color composite of Landsat-8 satellite imagery based on spectral indexes at 30m spatial resolution (pink/orange marks urban areas). Below: Black marks the urban extent in 2002 and 2015. (DLR)



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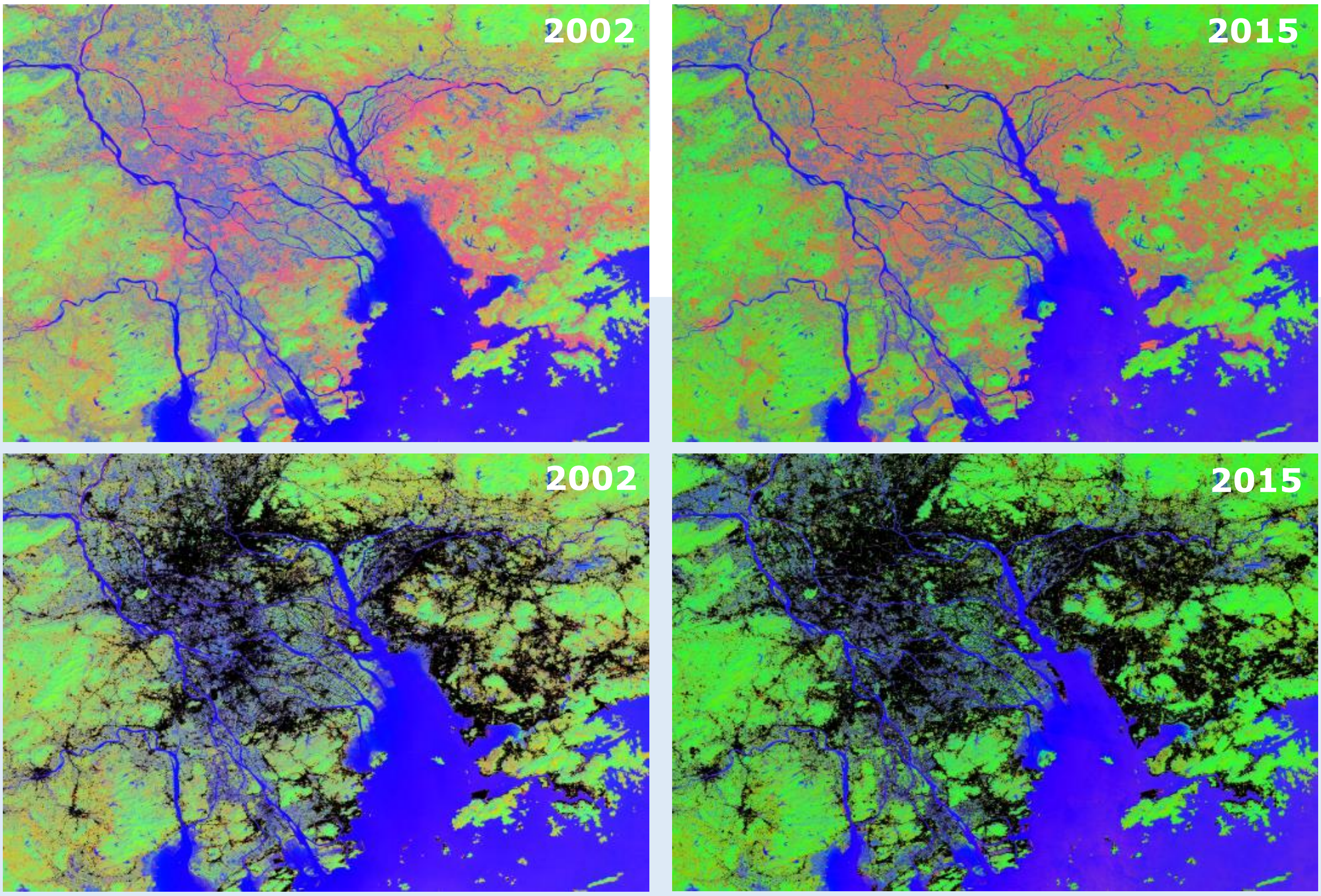

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Content and Use

The benefits of having green areas in cities is now an accepted and important component of urban development and planning programs supported also by the various development programmes. "Green cities" provide more livable cities for the inhabitants and critically assist in reducing the emissions from greenhouse gases in urban areas.

The amount of green areas within a city is an important urban sustainability indicator to assess the actual status in the attainment of the UN Sustainable Development Goals (SDGs). An important indicator related to green areas is "Green areas per 100,000 population" (applied by the World Bank (WB, 2008)). The availability of public green spaces in an urban context is a common indicator for urban planning, and the ratio of population versus the available area of green spaces or the Green Area Ratio (GAR) is an indicator of sustainability.

The product provides precise spatial information/location and extent of different green areas in the city.

These green areas include linear green features such as riverine habitats/woodlands, hedges and trees, as well as public parks, private gardens, forested areas, etc. Certain green density classes can be derived from the mapping such as density of green areas per urban block or cadastral parcel. Urban green areas can be also defined more broadly and focus on open spaces such as ecosystems occurring in the metropolitan areas that need conservation.

The product is also related to the land cover class soil sealing/surface imperviousness. Soil sealing describes the covering of the soil surface by materials such as concrete, which do not allow water to penetrate, forcing it to run off. Soil sealing maps help to understand the impact on the environment of urban expansion and development of related technical infrastructures. Mapping the extent of all such areas is of high importance as it is related to the risk of urban floods, to the urban heat island phenomenon as well as to the reduction of ecological productivity.

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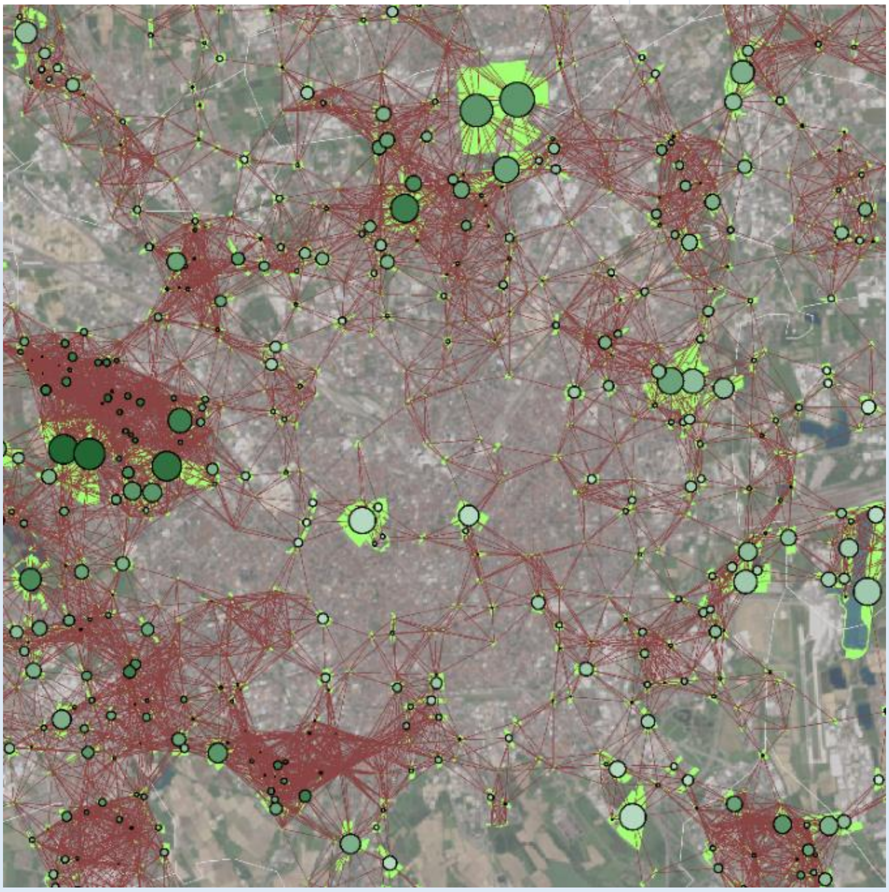


(1) Milan, Italy – Network of connected green areas located within 1km distance to each other. Mapping of green areas derived from Landsat-8 satellite imagery in 2014.
The size of the nodes is proportional to the extent of the associated green area. The darker the color, the higher the number of connections.
The map shows an insufficient numbers and extent of green areas in the south-eastern part of the city. (DLR)

Resolution, Availability and Frequency

Typical spatial resolutions are 5 to 50m, resulting in scales between 1:5,000 to 1:50,000. This resolution allows analyses on local to regional level.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

The update frequency of the product is usually once every one to five years. It is limited only by the availability of the satellite data.

Reliability

The geometric accuracy is usually comparable to the spatial resolution of the input data, normally extending to a few meters.

The thematic (classification) accuracy is higher than 85%.

Benefits

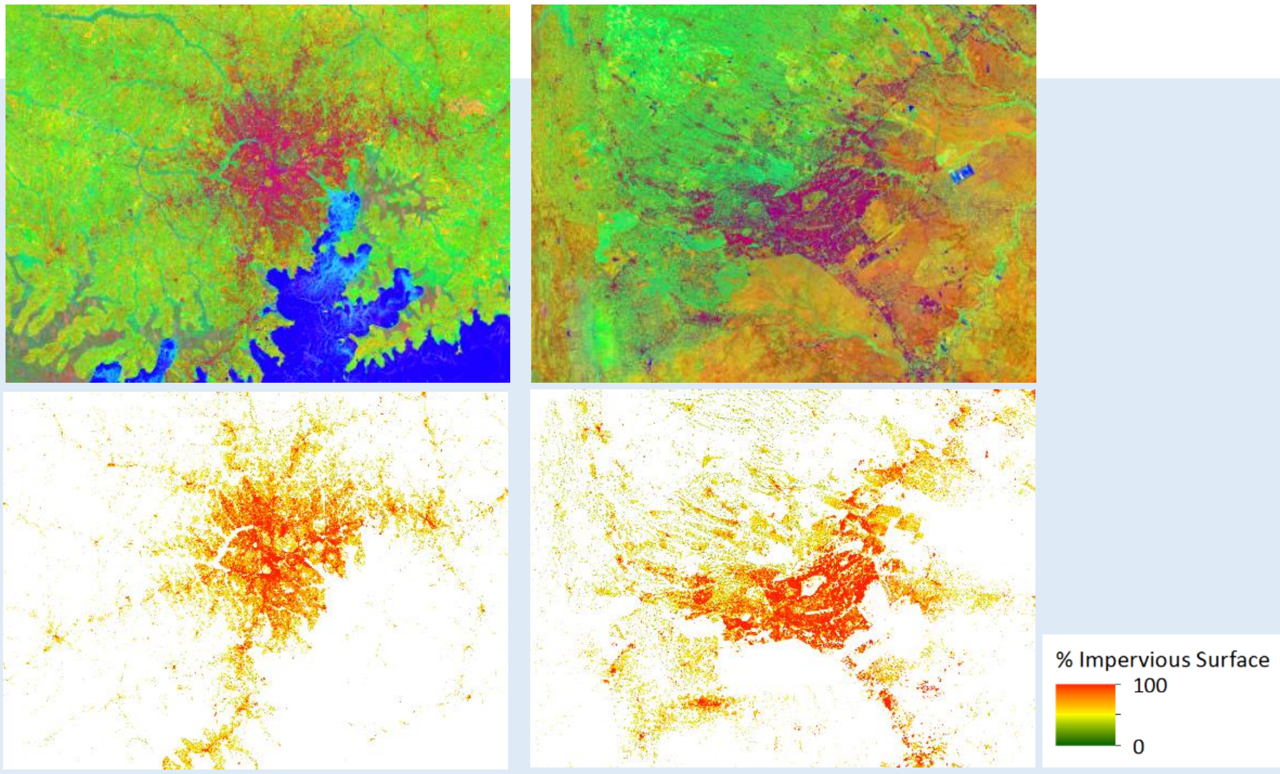
Satellite data allows the detection of green areas within a city in high temporal and spatial resolution and therefore provides not only up-to-date information of the examined city but also the possibility to perform spatial statistical analyses. The size and location of green areas is an important indicator for the assessment of a liveable and sustainable city. This product can provide the required information in a cost effective and harmonised manner.

(2)

(2) Green areas in Ostrava in 2012 extracted from SPOT 5 satellite imagery to support the monitoring of green infrastructure and potential development sites. (GISAT)

(3) Above: Color composite of Landsat-8 satellite imagery based on spectral indexes showing Kampala, Uganda (left) and Nairobi, Kenia (right) in 2015.
Below: Estimated percentage of impervious surfaces derived from 2015 Landsat-8 imagery of the cities Kampala (left) and Nairobi (right). (DLR)

(3)



Content and Use

Informal settlements are defined as settlements having inadequate access to safe water, sanitation and other infrastructure; the structural quality of housing is from impermanent materials and the settlements are often situated in geographically and environmental hazardous locations and they are overcrowded (WB, 2006, UN-Habitat 2003).

The haphazard development of informal settlements is in many cases a consequence of uncontrolled urban growth and represents a major challenge for urban planners and city authorities. Many countries have inadequate data and little knowledge on informal settlement locations, their spatial extent and growth patterns which thus hinders effective rehabilitation activities (WB, 2006).

The mapping products "Type of Informal Settlements" and "Extent of Informal Settlement" emphasize physical patterns and key characteristics of informal settlements such as growth (in terms of location and area), and type (phase of development of settlements, e.g. established/permanent or new developments). Spatial metrics such as compactness, patch size and density of buildings assist in definition of these settlements and can be pre-cursors to the application of indicators and deriving settlement typology.

These products can be used to support/distinguish two of the World Bank Global City Indicators "Area size of informal settlements as a percent of city area and population" and "Percentage of city population living in slums" (WB, 2008).

Further, the typology of informal settlements depending on location, construction material and its spatial patterns (built-up density) are crucial factors for estimation of the vulnerability to natural hazards and the assessment of related risks to the affected population.

(1)

(1) Informal settlements in Jakarta, Indonesia effectively detected and monitored with very high resolution satellite imagery from 2006 (above), and 2016 (below). (GISAT)

Resolution, Availability and Frequency

The spatial resolution of the product is between 0.5 and 1m resulting in 1:5,000 to 1:10,000 scale maps.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

The update frequency of the product is usually once every one to five years. It is limited only by the availability of the satellite data.

Reliability

The geometric accuracy is comparable to the spatial resolution of the input satellite data.

The thematic (classification) accuracy is can be up to 80 % for the informal settlement extent mapping. The informal settlement area evolution product has a thematic accuracy between 70% and 90%.

Benefits

As these settlements are dynamic with frequent population fluctuations, temporal and spatial high resolution EO data can provide city planners with data which would be otherwise difficult to obtain. Especially in developing countries where the accessibility is limited, traditional field mapping is difficult as well as time and cost consuming. Therefore, satellite data analysis is a unique planning tool for rehabilitation activities in and around informal settlements.

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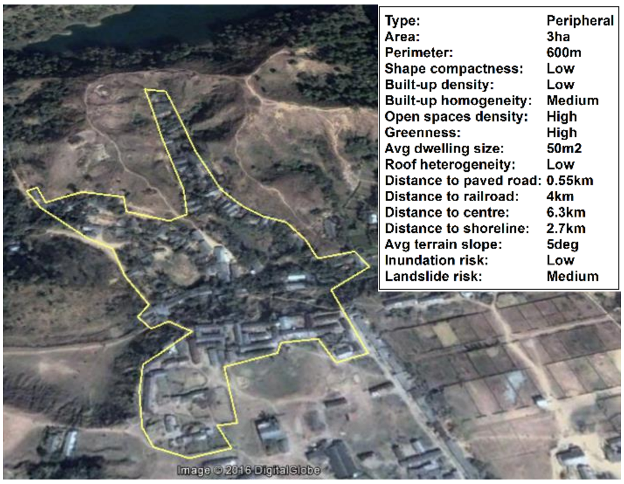
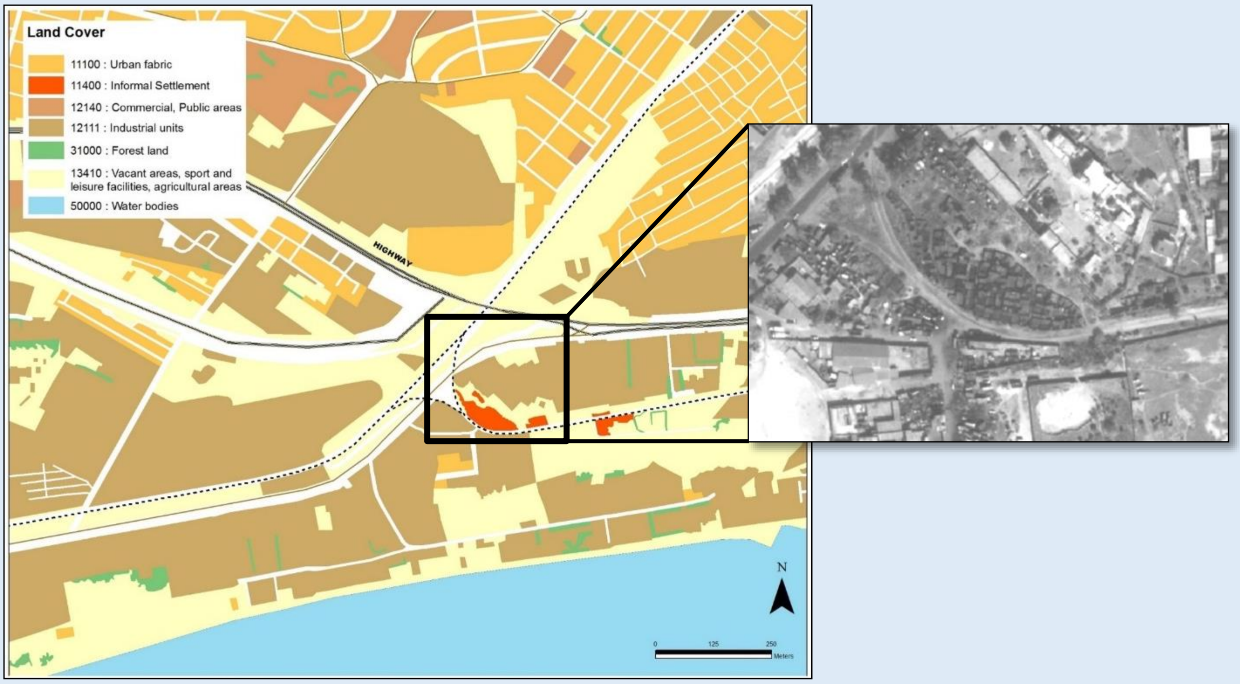


(2) Detailed characteristics of informal settlements mapped in Chittagong, Bangladesh in 2005 to support local urban planning policies. (GISAT)

(3) The detailed mapping of land use and land cover can include the identification of informal settlements as shown in this example for Dakar, Senegal in 2011 based on QuickBird satellite imagery. (SIRS)

(3)



Content and Use

Assessment and monitoring of building footprints (building outlines on the individual building level) are a pre-requisite for urban planning. Identifying these footprints allows the generation of building inventory maps, calculation of the square meters of individual buildings and the total area of the entire building stock in the area of interest, building density, open spaces and spacing between buildings, building type or building material as well as locations for water and sewer lines. It is further possible to estimate the construction process of new houses and proximity to roads and other visible infrastructure. Building footprint maps also provide information on the level of granularity in cities.

Additionally, it is possible to estimate the height of the building by using specialised software to process stereo imagery (two images of the same area taken from different perspectives).

The information derived with urban footprint maps can be summarised in building type maps. The building footprint product distinguishes between industrial buildings, commercial buildings, residential buildings, farm buildings, public buildings, health buildings and educational buildings, etc. These building type maps allow the understanding of the organisation and the spatial distribution of activities, services and housing, etc. within a city and can be therefore used as a tool for managing the city’s spatial structure (Kaw & Roberts, 2016). The information also helps in the assessment of building risks from natural hazard; the building material is an indicator of the vulnerability to floods or earthquake, and thus specific prevention activities can be undertaken by the Municipalities.

In combining the building footprint with the building height product the Floor Area Ratio (FAR) Indicator can be derived; the FAR is a key mechanism for urban planning authorities, as many cities use it as regulatory framework.

(1)

(1) Precise identification of building footprint and building type is necessary for a variety of purposes and notably to assess potential casualties/damages in the case of natural disasters such as in the earthquake that hit Quintero, Chile in 2015. (SIRS)

Resolution, Availability and Frequency

Typical spatial resolutions for the assessment of building footprints are between 0.5 and 1m, resulting in scales of 1:1,000 and 1:3,000.

Satellite data is available globally every few days/weeks, depending on the geographic latitude, cloud cover and data acquisition schedule.

The update frequency of the product is usually once every 3 to 5 years, but is limited only by the availability of satellite data.

Reliability

The positional accuracy of the product is around +/- 5m. It defines the closeness of the location of spatial objects in the dataset in relation to their true positions on the earth's surface.

The thematic (classification) accuracy is between 80 and 90%.

Benefits

The very high resolution satellite data allows the identification of single houses and related attributes for vast areas in a very short time. Due to the high temporal availability of satellite data and the possibility to provide historic data, comprehensive analyses about the development and trends of spatial urban patterns are possible.

The analyses of building types from EO data offers time-cost benefits compared to the traditional field visits. They allow the detection of vast areas with high detail, in a short time. In many developing countries there are constraints on accessibility and current registers are outdated in some parts of the city; thus the building footprints and building type products provide an effective solution to these problems.

(2) This example illustrates the identification of new build-up houses in Taschkent, Uzbekistan. Above: SPOT 5 satellite imagery in 2009, before building construction (a) and PLEIADES satellite imagery in 2014, after building construction (b). Below: detailed land use map on building block level in 2009 (c) and in 2014 (d). (GAF AG)

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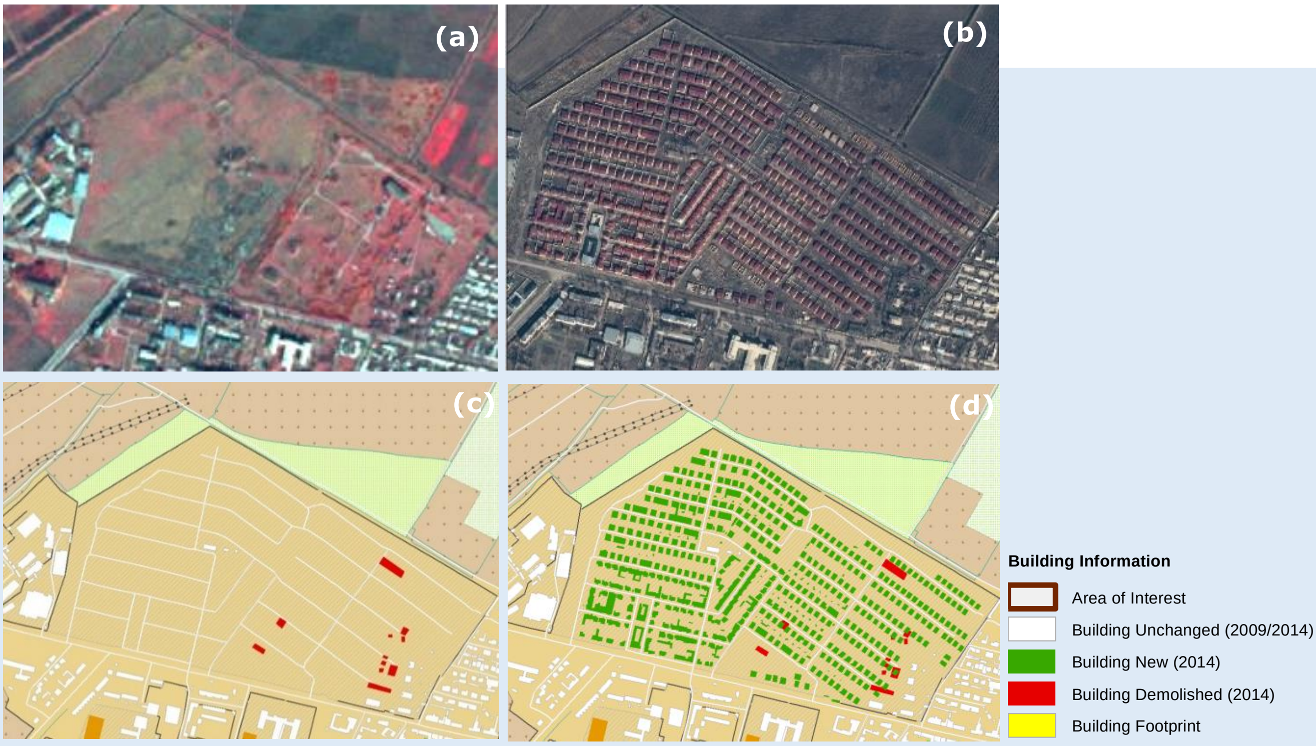

Content and Use

Reducing traffic congestion and improving the overall efficiency of transportation networks remain major issues that developing countries have to address as part of the rapid urbanisation. Urban transport infrastructure improves opportunities for cities becoming sustainable, prosperous and liveable cities (WB, 2016).

The product "Transport Infrastructure" involves the mapping of different transport classes such as fast transit roads, primary and secondary roads, railways, port areas and airports, etc. Additionally, it delineates road width profiles, block areas formed by roads and lengths of street frontage. The product can be fit to user requirements.

The product can be also used to determine the Global City Indicator "Km of transportation system per 100,000 population" applied by the World Bank (WB, 2008). This indicator is an important tool to assess the cities performance in becoming a sustainable, green and competitive city (WB, 2008). This product can also support the important concept of Transit Oriented Development (TOD) which requires that current transit areas or corridors to be identified in order to assess the types of potential land development possible in these areas.

Other applications of the product include identifying the number of lanes in an area to locate potential bottle-necks in a network as well as knowing if a road network is undersized. The product could also be used to derive average pollution models if coupled with 3D buildings.

For an integrated and holistic approach to transport planning, maps showing the actual transport structures help to visualise improvable spatial forms and facilitate the future provision of infrastructure (WB, 2010).

Resolution, Availability and Frequency

The spatial resolution for this product is 0.5 and 1.0 m, resulting in 1:5,000 to 1:20,000 scale maps. However, if needed the resolution can be increased.

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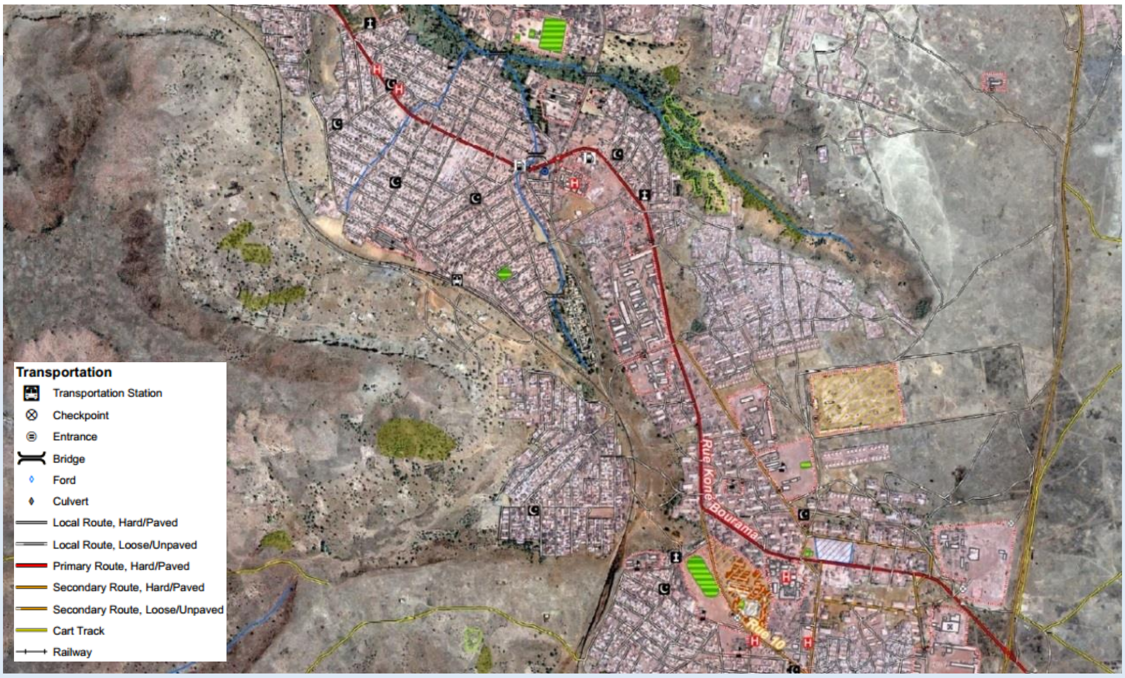

(1) In the absence of reference mapping, transport infrastructure can be identified and mapped from very high resolution satellite imagery as shown in Kati, Mali. (SIRS)

Satellite data is available globally every few days/weeks, depending on the geographic latitude, cloud cover and data acquisition schedule. The update frequency of the product is usually once every 3 to 5 years.

Reliability

The positional accuracy of the product is +/- 5m. It defines the closeness of the location of spatial objects in the dataset in relation to their true positions on the earth's surface.

The thematic (classification) accuracy is between 85 and 95%.

Benefits

Maps of different city features like the transportation infrastructure can be produced in high temporal and spatial resolution as well as in a harmonised and up-to-date manner with EO data.

The maps are especially useful in conjunction with maps of other infrastructure systems, such as water or solid waste. The method of visualising different GIS layers on top of satellite imagery has become a powerful tool for urban planners.

(2)


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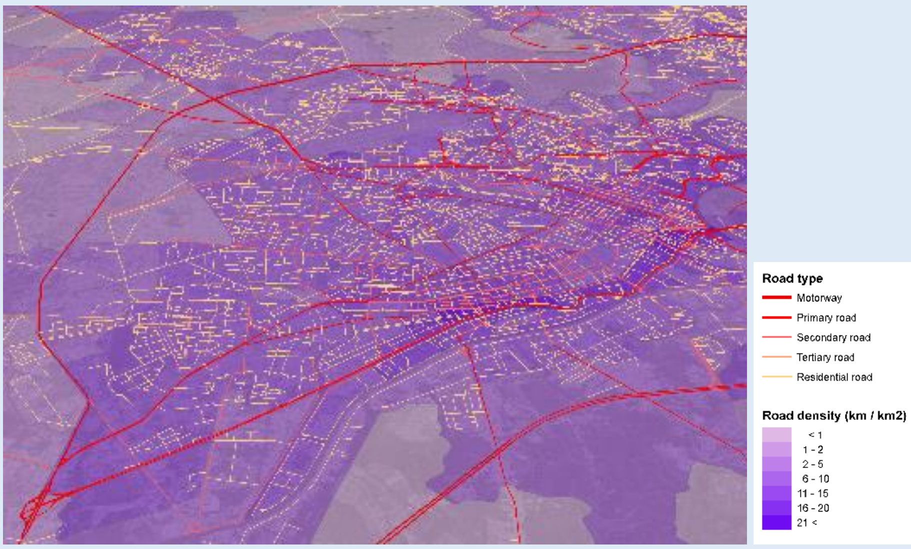

(2) Infrastructure development in Agadir, Morocco. Above: Worldview-2 data as baseline, Below: Vector map, including building footprints, urban fabric thematic classes, streets, power lines, thematic land cover classes, airport runway and taxi ways. (GAF AG)

(3) Road typology and density per administrative unit in Ho Chi Minh City, Vietnam in 2013. The analyses is based on Rapid Eye satellite imagery. (GISAT)

Content and Use

In many developing countries rapid urban expansion is having negative impacts on the ecosystems of the peri-urban areas; for example removal of forests/vegetation, wetland destruction, soil degradation and resulting erosion. Whether it is the ecosystems around in-land or coastal cities that are being degraded, there is a negative impact on the vulnerable population living in the peri-urban areas as well as on the urban population.

EO data can be used for the mapping and assessment of urban ecosystems and their services; examples of the type of assessment that can be provided include mapping urban green infrastructure, assessing the condition of urban ecosystems based on indicators for pressure, state and biodiversity, and assessing the delivery of ecosystem services.

The ecosystem status product provides several indicators describing ecosystem potential and limiting factors for ecosystem service provision due to development of urban areas and related infrastructure. The fragmentation indicator for example provides information on landscape fragmentation by roads, production and service infrastructure; additionally the land take indicator is related to land take by the expansion of residential areas and construction sites. In order to assess condition and biodiversity of urban ecosystems, the following indicators based on EO data can be used: urban green areas, green linear elements and trees, urban and peri-urban agriculture.

The products are also based on urban extent and/or urban and peri-urban land use/land cover products.

Resolution, Availability and Frequency

The overall spatial resolution based on raster grids or administrative units and can be between 100m to 1km.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

The update frequency of the product is usually once every one to five years. It is limited only by the availability of the satellite data.

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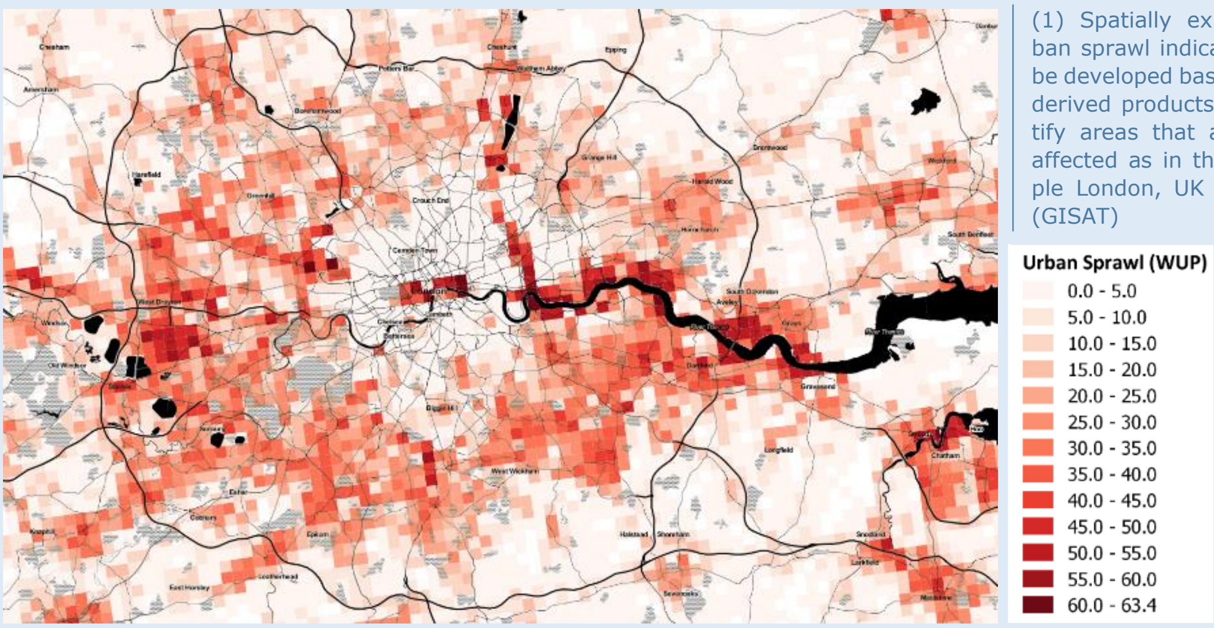


(1) Spatially explicit urban sprawl indicators can be developed based on EO derived products to identify areas that are most affected as in this example London, UK in 2014. (GISAT)

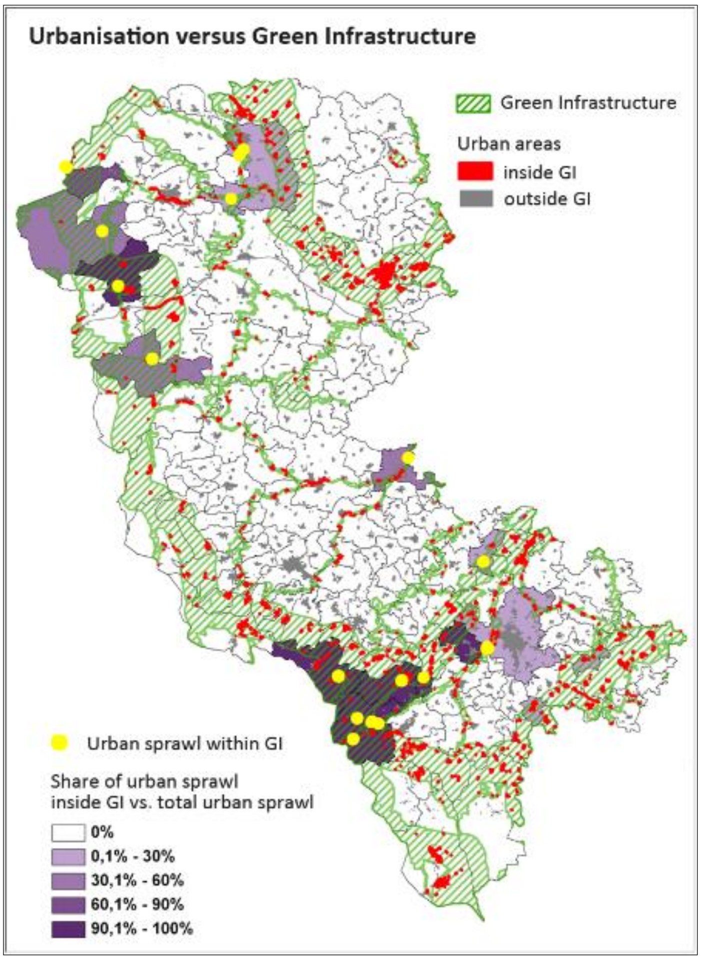
Reliability

The geometric accuracy is usually comparable to the spatial resolution of the input data, normally extending to a few meters.

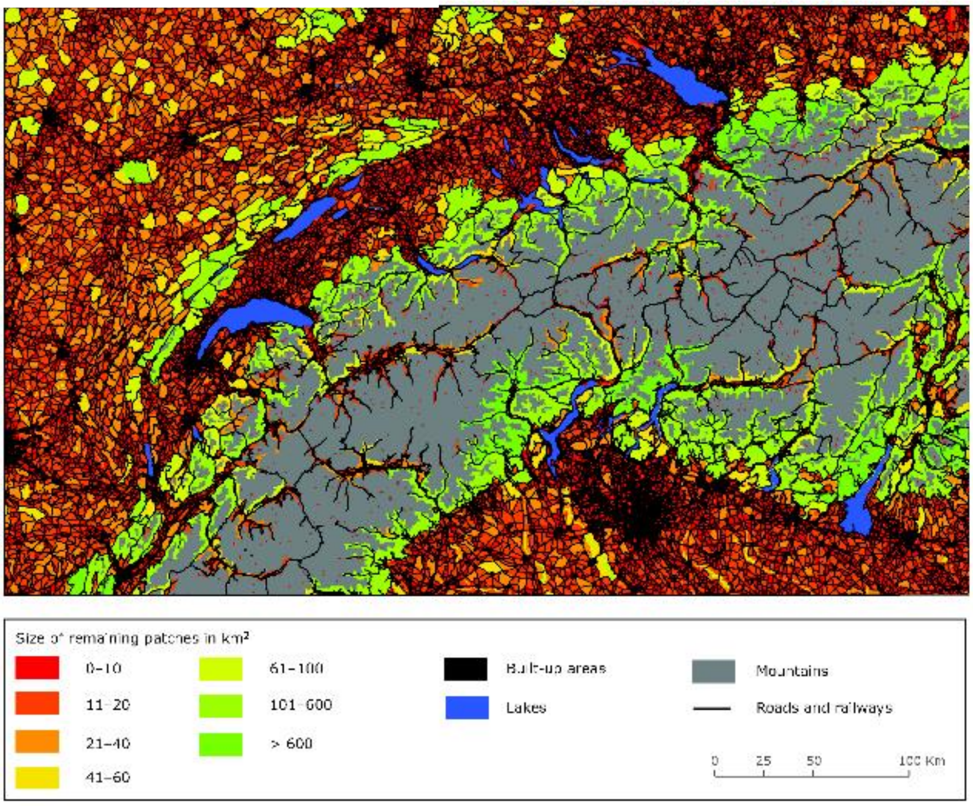
The thematic (classification) accuracy is between 75-80%.

Benefits

City planning requires information on the state of green areas/ecosystems and land use in short time intervals and in high spatial and spectral resolution. This demand can be supported by the EO based products with high spatial information available over a period of time for monitoring. With the arrival of costing of Ecosystem Services Loss in urban planning, there will be more efforts to protect areas at risk and ensure maintenance of Ecological Corridors in city plans.



(2) The destruction of green infrastructure due to urban expansion can be visualised here for the Pilsen District, CZ in 2014. (GISAT)



(3) Map showing the fragmentation of habitats by urban and transport infrastructure. The analyses covers a part of Switzerland, Germany and Austria in 2014. (GISAT)

Population Distribution and Density

PRIMARY PRODUCTS

Content and Use

Population distribution and density assessments are both crucial variables for sustainable urban development and urban security applications (e.g., planning of evacuation measures). The estimation of the urban population distribution and density is an important indicator for the assessment of urban growth, and planning for city services. The derived information can be also very helpful in hazard risk prevention and assessment as well as for the definition of special human-related indexes.

The product "Population Distribution and Density" is estimated for a geographically referenced system of grid cells (50m to 1km) instead of a hierarchical system of administrative units.

In addition, population distribution can be also estimated for individual urban blocks based on 2D or 3D data.

The available information contains the number of inhabitants and the population density (optionally classified as high, medium, low) at detailed scales.

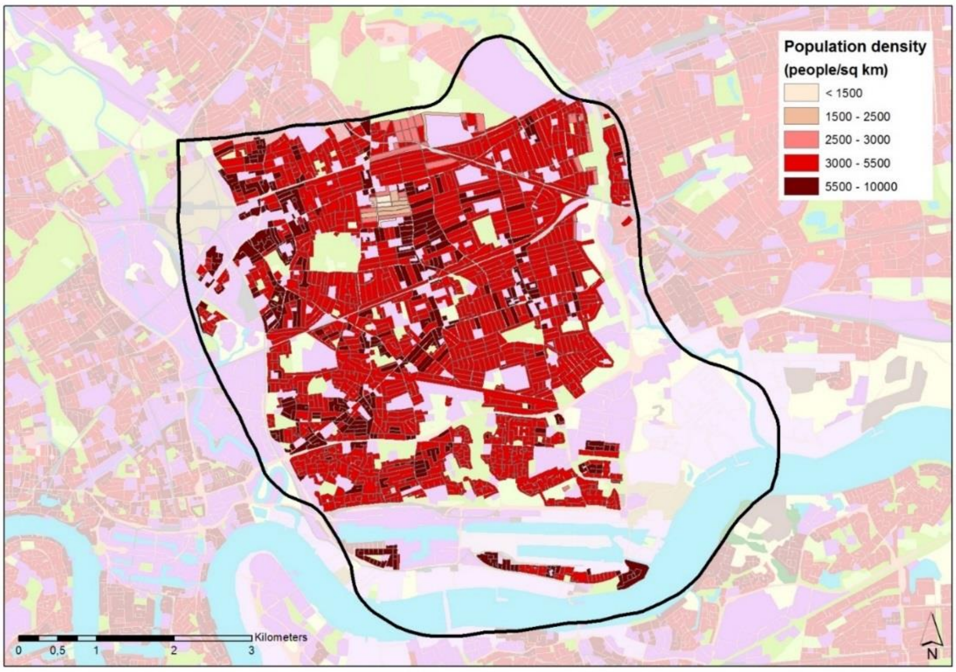
Resolution, Availability and Frequency

The spatial resolution of most urban mapping products can be up to 0.5m, depending on the input imagery resolution. Construction classes can be estimated from block level, resulting in 1:5,000/ 1:10,000 scale maps to lesser detailed maps, resulting in 1:100,000 scale maps.

The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

The update frequency of the product is usually once every one to five years.

(1) Land use / cover maps can be used to disaggregate population census data to create a spatially explicit map of population density for the London Borough of Newham, UK. (SIRS)

(1)


Reliability

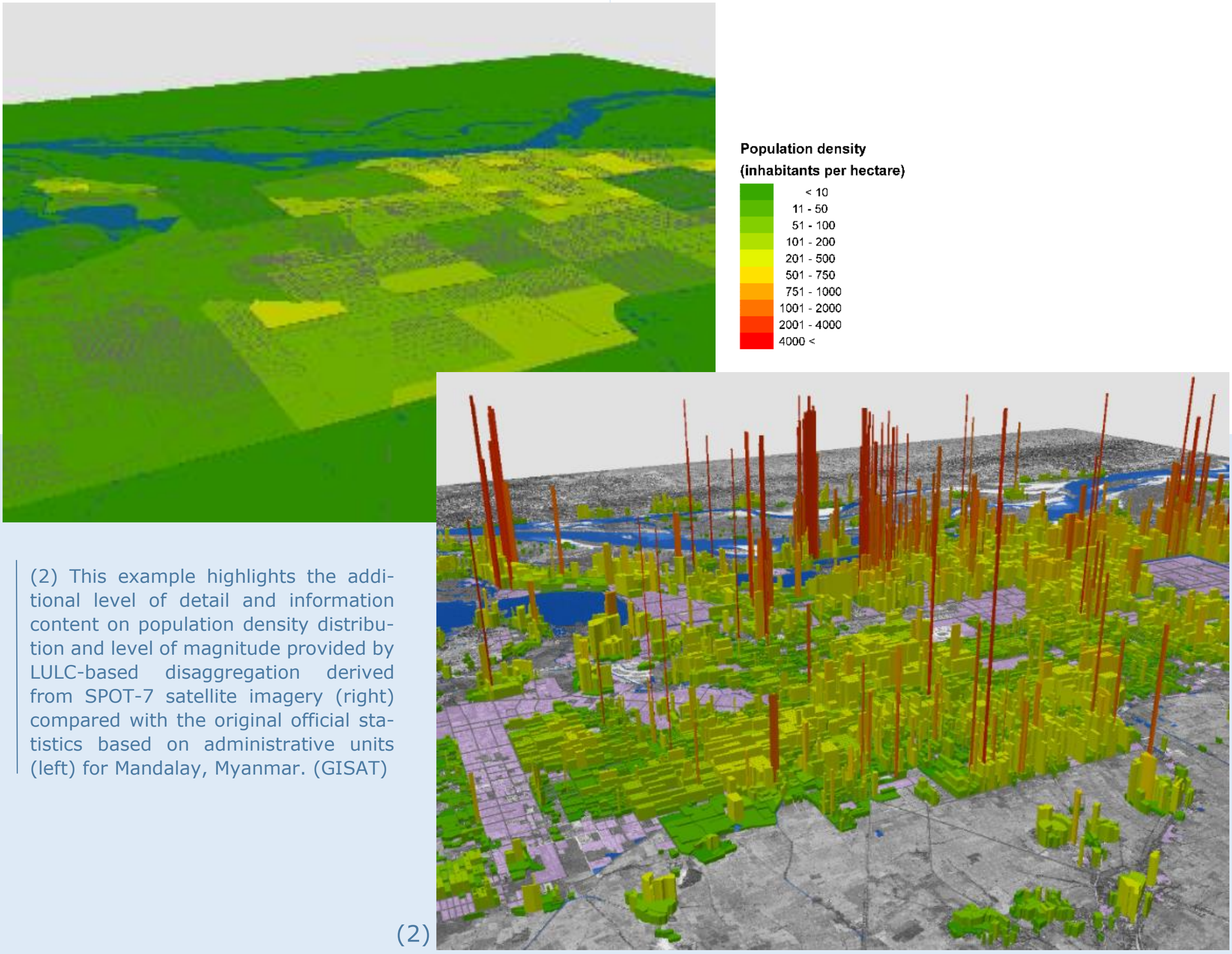
The geometric accuracy is usually comparable to the spatial resolution of the input data, normally extended to a few metres.

The thematic (classification) accuracy is between 70% and 90%.

Benefits

Population estimations based on undertaking conventional census exercises are time-consuming, costly and difficult to update. Moreover, the census data is usually provided as aggregated figures only at district level and the census interval is usually inadequate for urban planning, resource management and service allocation.

In contrary, the population estimation by EO data represents a cost-efficient solution; it allows not only the estimation of population distribution and density of the past but also of the actual status in a regular and high temporal resolution.



(2) This example highlights the additional level of detail and information content on population density distribution and level of magnitude provided by LULC-based disaggregation derived from SPOT-7 satellite imagery (right) compared with the original official statistics based on administrative units (left) for Mandalay, Myanmar. (GISAT)

(2)

Waste Sites

Content and Use

Solid waste management is an urban service key element under urban development. Solid waste services include waste collection, transfer, recycling, resource recovery and disposal. Especially clandestine solid waste accumulations are often improperly disposals of waste which have detrimental impacts on the environment (WB, 2012).

The product "Monitoring Waste Sites" locates and maps different kind of waste disposal sites. The product focuses on the detection of two defined classes, which assigns the status of the waste site as legal or illegal. Ancillary data of the legal waste sites is needed to make the distinction between both classes.

The waste situation maps produced within this product demonstrate the size, location and change of waste sites and help to detect illegal ones. These maps can be used by city planners to establish an integrated sustainable waste management plan.

In conjunction with other products (population density, land use) an estimation of the populations that can be affected by hazardous waste and pollution due to these waste sites can be estimated.

Resolution, Availability and Frequency

The product can be mapped in very high spatial resolution (up to 0.5m). However, the resolution can be fitted to the customer's needs.

Satellite data is available globally every few days/weeks, depending on the geographic latitude, cloud cover and data acquisition schedule.

The update frequency of the product is usually once every 3 to 5 years.

Reliability

The geometric or positional accuracy is usually comparable to the spatial resolution of the input data; for this product the positional accuracy is +/- 2m.

The thematic (classification) accuracy can be up to 85% depending on landscape characteristics and type of waste site.

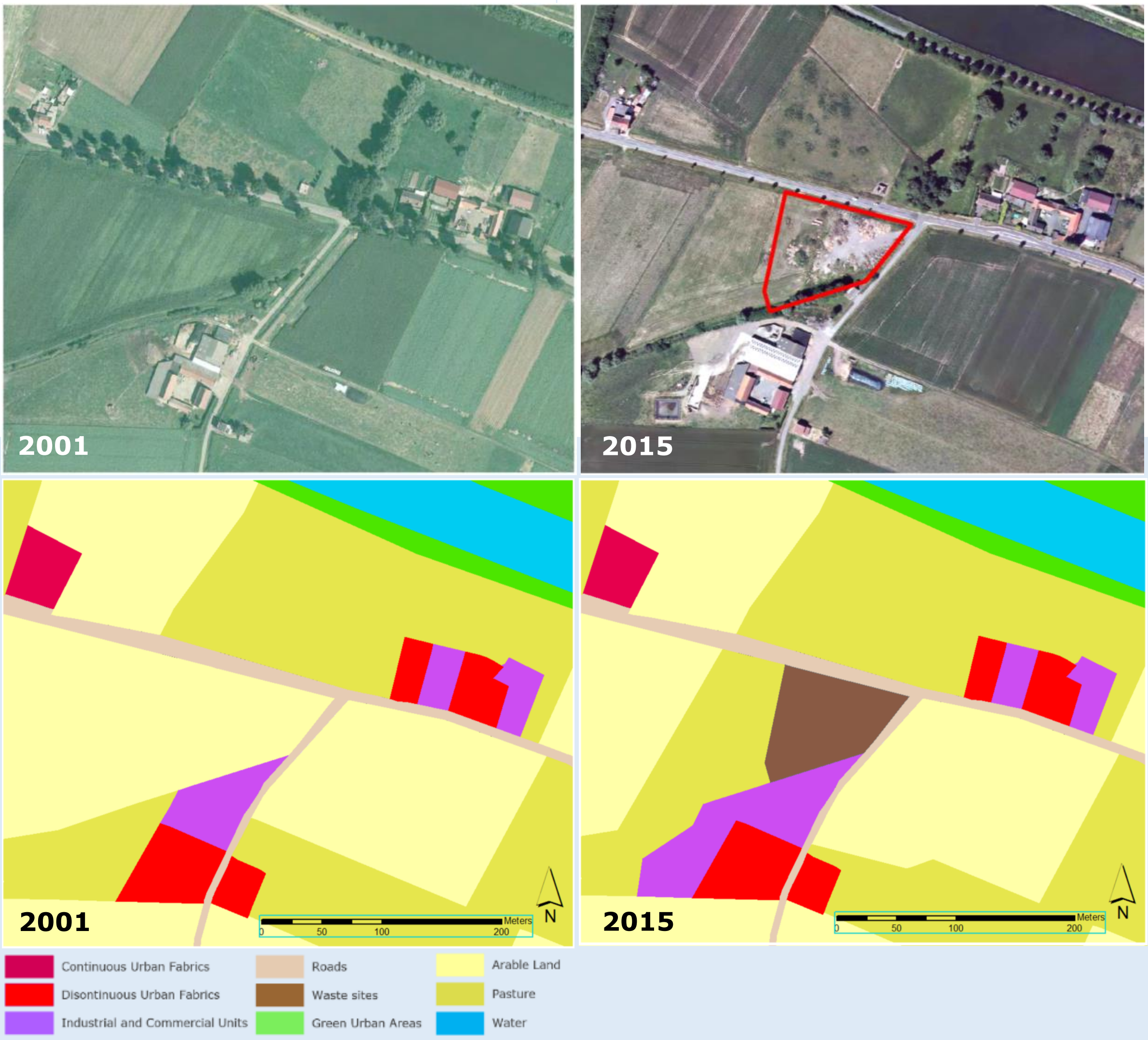
(1) Detected waste sites

(1) The use of very high resolution EO imagery makes it possible to detect and monitor informal/illegal waste sites. (SIRS)

Benefits

The monitoring of both legal and illegal waste sites in urban areas has an important impact on curtailing health hazards and risks to the urban population and environment. The application of EO data for identification of these sites provides both a cost effective and routinely available monitoring mechanism, which can greatly support urban regulatory frameworks on waste disposal.

(2) Identification of an illegal waste/dump site in northern France appearing between 2001 (left) and 2015 (right). (SIRS)



(2)

Content and Use

According to the World Health Organisation (WHO) air pollution is now the world's largest single environmental health risk. Approximately 7 million premature deaths worldwide, predominantly in cities, are attributed to air pollution each year (WHO, 2014). Even a long-term exposure to low pollution levels of particulate matter, nitrogen dioxide and ozone may cause serious health effects. Therefore, the long-term monitoring of air pollution in cities is a prerequisite for a sustainable development and for assuring quality of life.

The product consists of multi-temporal maps and time series of the air pollutants NO_2, SO_2 and O_3 delivered as tropospheric vertical column densities [μg/m² or molecules/cm²]. For the aerosols multi-temporal maps and time series of the aerosol optical depth are delivered.

The product allows the monitoring of air pollution trends and the spatial variability. NO_2 for example is often used as a proxy for fossil fuel-based energy consumption and other co-emitted greenhouse gases as well as a predictor of the effects of air pollution on health. The product can contribute to develop and monitor emission related policies or mitigation measures.

Resolution, Availability and Frequency

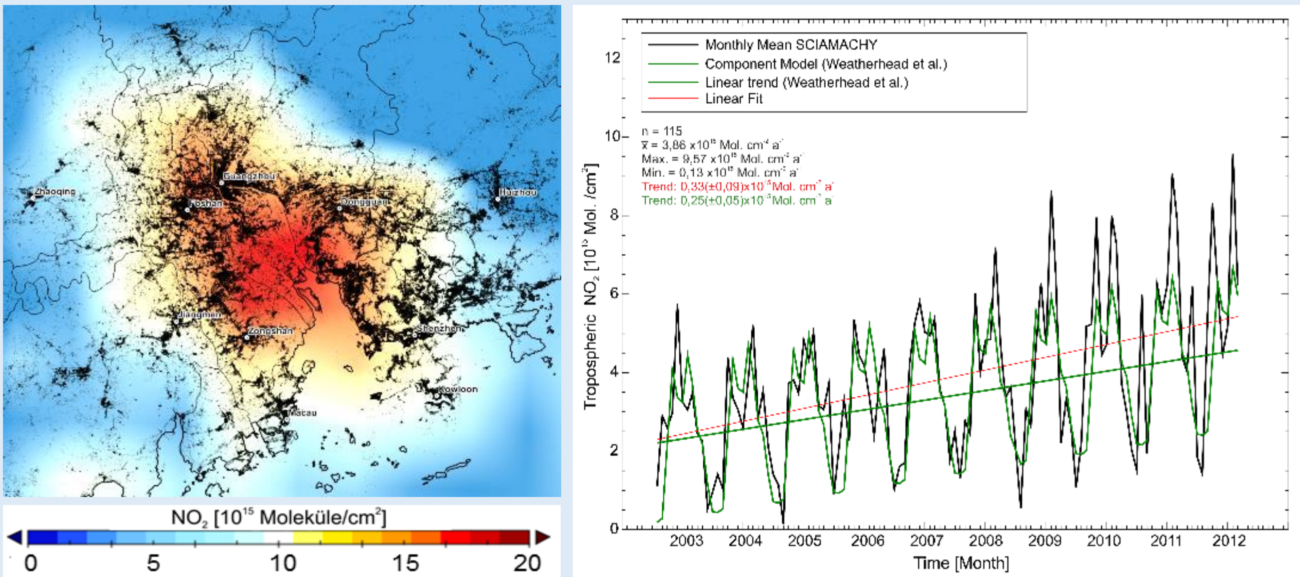
Using a wealth of satellite-based instruments the air quality monitoring product has been available almost daily from 1995 to present.

Since the air pollutants are retrieved using atmospheric spectroscopy, the spatial resolutions are lower than for other products of this portfolio. Their range varies between 3x3 km up to ~28x28 km at the equator.

Reliability

The accuracy is strongly dependent on the instruments used and the gasses considered. The GOME-2 mirror positioning accuracy in fixed pointing will be better than 0.03 deg. (~800 m on the ground), while in scanning modes it will depend on actual speed, but will anyway be better than 0.065 deg.; for the MODIS satellite data positioning accuracy is 50 m.

(1) The level of economic/industrial activity in the Pearl-River-Delta region, China is illustrated by the Nitrogen dioxide (NO2) average for 2002 to 2012 (left) as derived from ENVISAT/SCIAMACHY.
These data can also be summarised for an entire city (right) with a NO_2 time series for Dhaka, Bangladesh from 2002 to 2012 (ENVISAT/SCIAMACHY). Monthly mean values are depicted. The data reveals a significant increase in NO_2 of 6.5 ± 1.4%/year which ca be linked to urban growth. (DLR)



(1)

The thematic accuracy for NO_2 measured by GOME-2 for polluted cities is between 40 and 80%; by OMI at around ~20% (polluted). Since monthly means are calculated, the accuracy is significantly improved. Pollution trends can be quantified better than 2%.

The products are not available under cloudy conditions. For O_3 and SO_2 the sensitivity to the surface layer is strongly limited.

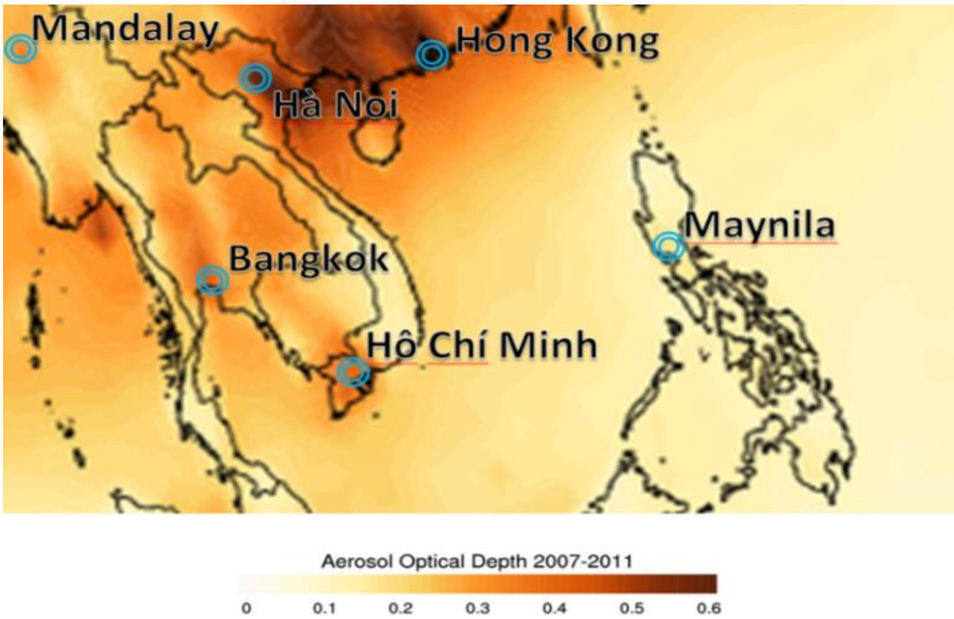
Benefits

Measurements of ambient air quality are often sparse. Even if they are available the measurement sites are often not representative for whole cities or urban agglomerations. Air pollution data and time series from earth observation are independent, up-to-date and available practically around the world. Contrary to ground-based measurements, the data is integrated over larger areas. The product is harmonized, consistent and comparable.

(2) Aerosol Optical Depth over South East Asia between 2007 and 2011. (DLR)

(3) Quantification of NO_2 trends in %/a in China. Analysis is based on GOME-2 data between the years 2007 to 2013. (DLR)

(2)



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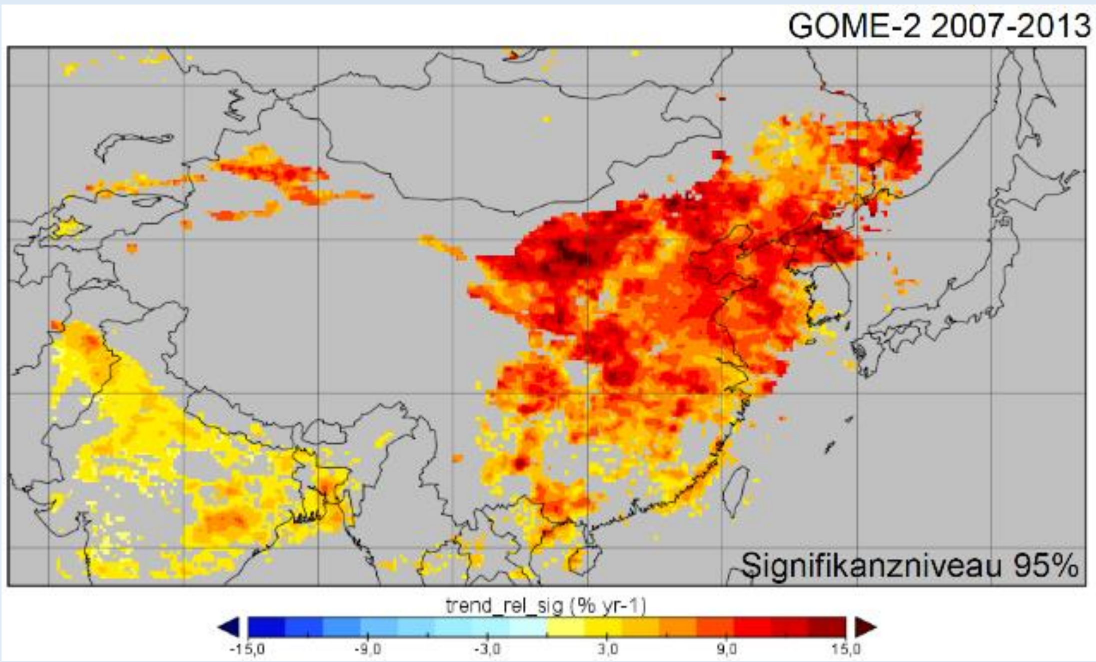


Urban Heat Islands

Content and Use

Urban development results in a dramatic impact on the environment, affecting also on the micro-climates of cities. The Urban Heat Island (UHI) may be described as the differences in observed ambient air temperature between cities and their surroundings. The knowledge of the Urban Heat Islands is crucial to a spectrum of issues and topics related to urban climate, global change and human health.

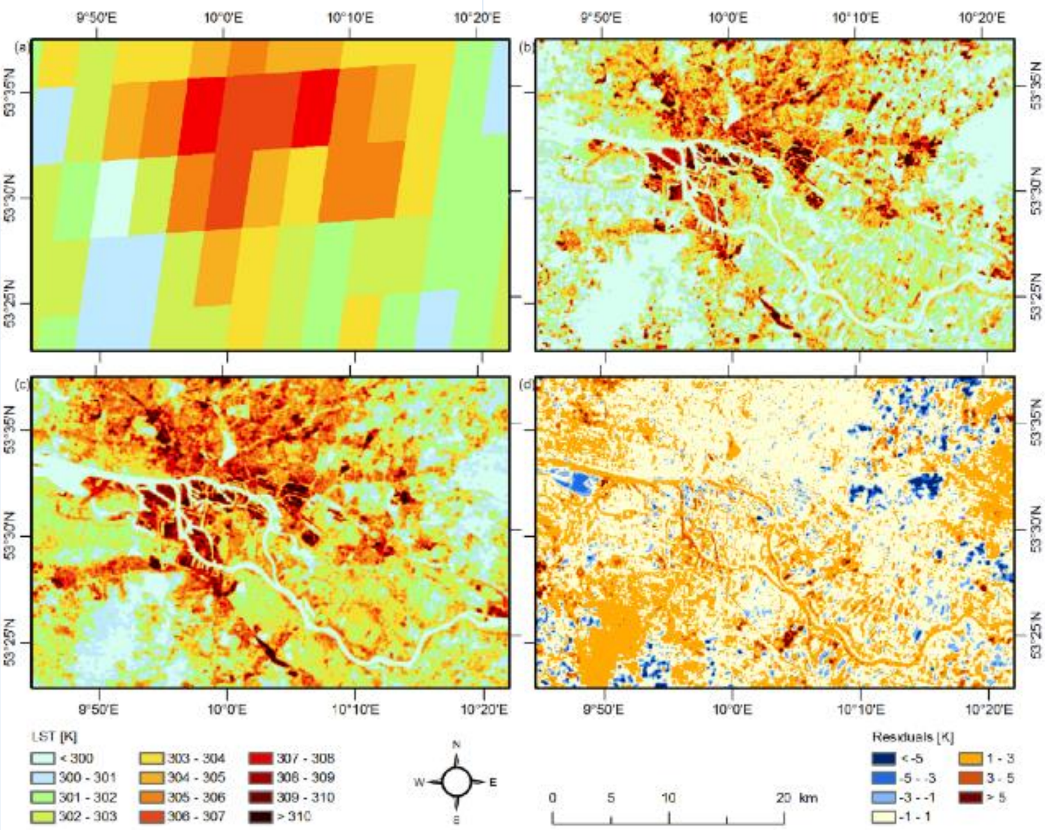
The product contains maps and time series of land surface temperature to monitor the UHI and track its spatial and temporal variability.

The Urban Heat Islands contribute to global warming. In addition, higher urban temperatures result in higher ground-level ozone concentrations with their adverse health effects. Higher urban temperatures lead also to higher energy consumption, mainly due to a stronger demand for air conditioning. Knowledge about the Urban Heat Islands is important for urban planning and managing practices.

Resolution, Availability and Frequency

The spatial and temporal resolution varies depending on the satellite data used for this product. Geostationary instruments like the meteorological satellites (e.g. MSG/SEVIRI) deliver data at a coarse spatial resolution of 3km but have a repetition rate of 15 minutes. As a compromise sensors with improved spatial resolution are available like AVHRR, MODIS or Sentinel-3. These instruments are characterised by a spatial resolution better than 1km and at least two overpasses per day.

(1) Monitoring of the Urban Heat Island of Hamburg observed with a trade-off between spatial and temporal resolution with SEVIRI every 30 min (left) and ASTER every 16 days (right). (DLR)



(1)

Reliability

The accuracy varies with the applied instrument. The pointing accuracy of MODIS is 90 arc seconds.

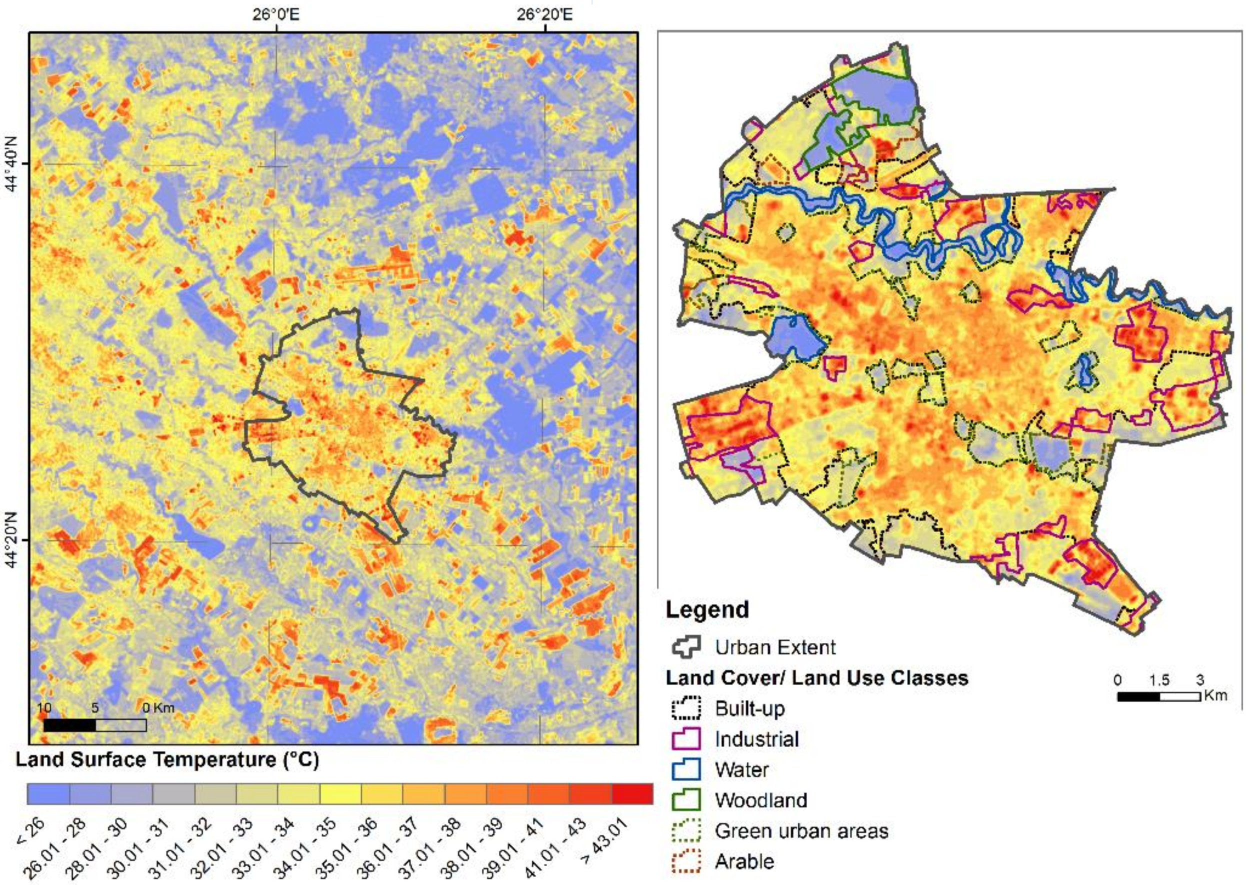
The thematic accuracy of MODIS for surfaces with a known spectral emissivity is around 0.5K. For MSG/SEVIRI it is ±1.5K.

Benefits

The Urban Heat Islands product can contribute to revise urban design and landscaping policies for mitigating the adverse thermal effects of building geometry, high building mass, and poor landscape patterns.

The UHI monitoring by means of Earth Observation is independent and available practically around the world. The product delivers the land surface temperature data on a homogenous and consistent grid. No ground-based measurements are required.

(2) Left: Urban Heat Island of Bucharest, Romania. Land Surface Temperature estimation based on Landsat 8 OLI/TIRS data, from July 2015, showing continuous high temperatures within the urban extent. (GISBOX)
Right: Overview of Bucharest. Spatial distribution of land surface temperature according to land use / land cover classification clearly depicting the role of industrial activities in relation to heat islands. (GISBOX)



(2)

Elevation Product, Building Height, 3D Models

Content and Use

The building height and 3D models provide proper delineation of the extent of built-up areas, as well as a precise estimation of building heights which are required for reliably characterising the building volume; this can furthermore support the estimation of population distribution. Building height is of great importance when modelling anthropogenic heat fluxes. Furthermore, the height models in conjunction with building footprints can provide the Floor Area Ratio (FAR) required in many urban planning regulatory requirements.

The information derived with the building 3D product can be used for a range of follow on products; for example next to a high quality Digital Surface Model (DSM), the building height can be estimated on single building block level. This allows the estimation of population and population growth, of the population density, the total number of households within a city, and can support the risk assessment and disaster management plans in a city.

Resolution, Availability and Frequency

The spatial resolution is between 0.5 and 12m, the equivalent scale is 1:5,000m.

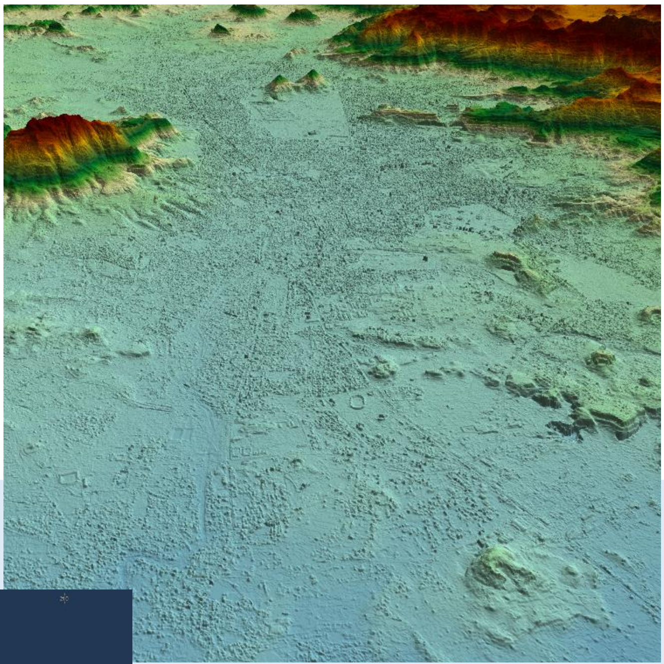
The temporal availability of the satellite data depends on the geographic latitude, cloud cover and data acquisition schedule and therefore ranges between a few days to weeks.

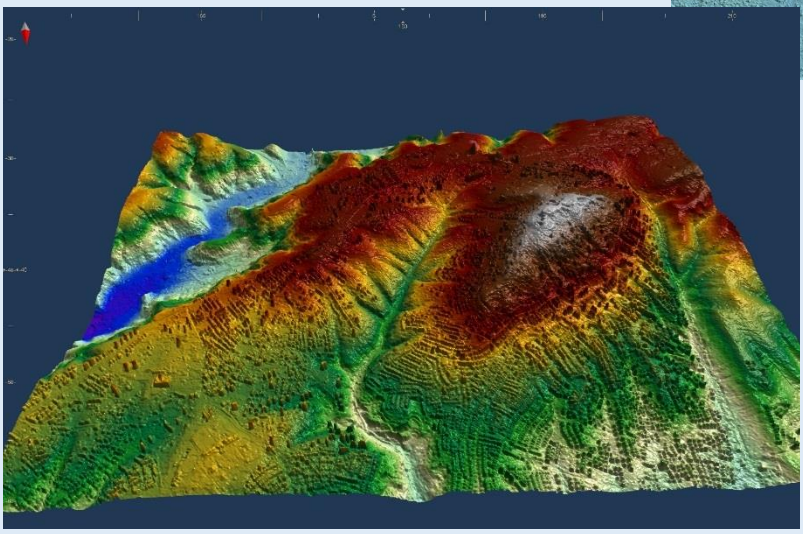
The update frequency of the product is usually once every one to five years. It is limited only by the availability of the satellite data.

Reliability

The geometric accuracy is usually comparable to the spatial resolution of the input data, normally extending to a few metres.

The thematic (classification) accuracy is around 95% depending on the quality of the EO data.



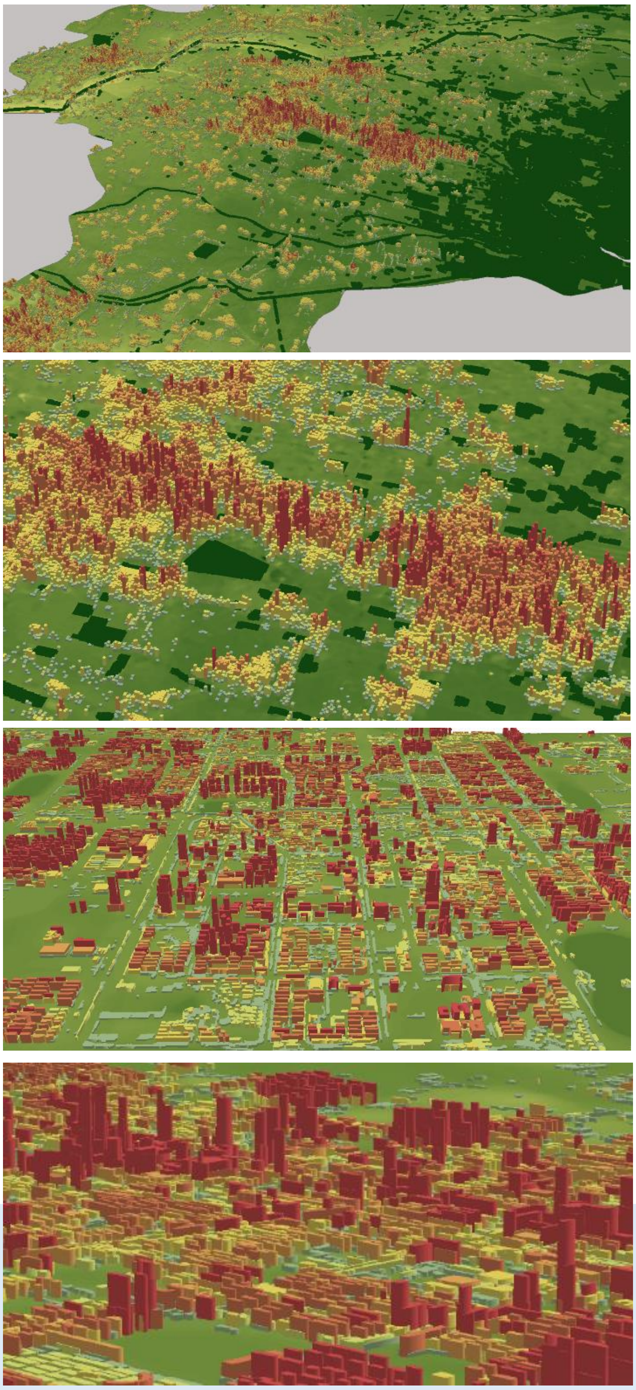


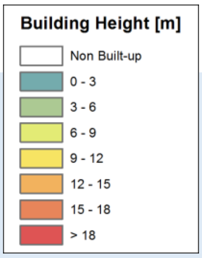
(1)

(1) Euro-Maps 3D high resolution Digital Surface Model of Sanaa, Yemen (above) and of Ankara, Turkey (below) in 2014. (GAF AG)

Benefits

Building height and 3D models are essential for multi-dimensional urban planning and design; for example the distribution of buildings with different heights and the ability to visualize blocks of high-rise buildings provide planners with spatial information for locating new telecommunication lines and other services. The reconstruction of a city via 3D models supports improved and efficient urban planning decisions. The application of EO data for building height and 3D models provides information which is scalable and accurate compared to traditional methods.



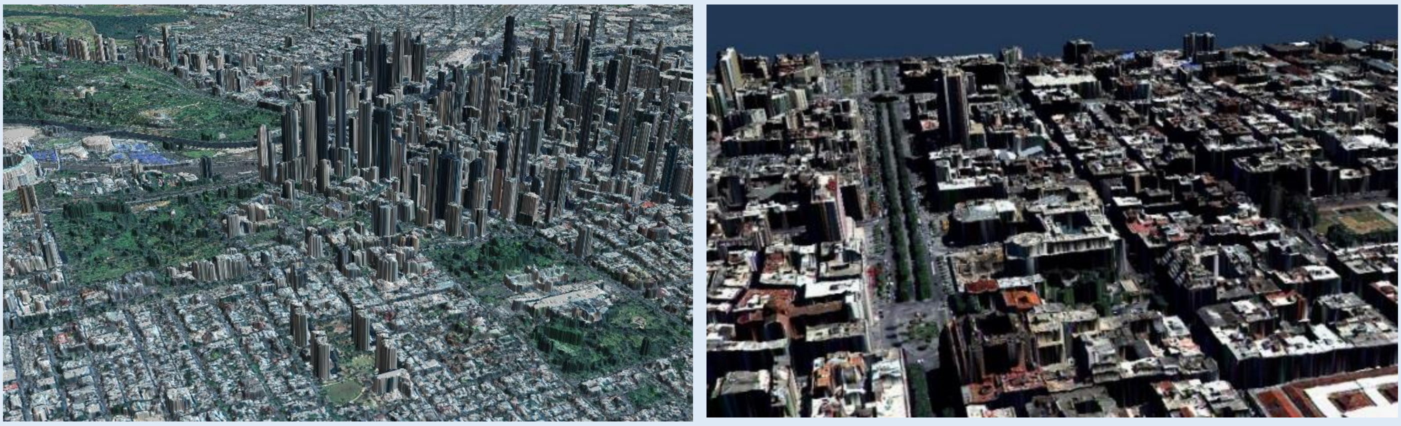


(2)

(2) Building high estimation in Dongying, China - 3D model derived by means of PLEIADES satellite imagery at 4m spatial resolution which can be used for building extraction. (DLR)

(3) High quality Tri-Stereo Digital Surface Models with corresponding ortho image of Melbourne, Australia (left) and Tunis, Tunisia (right). The 2m and 0.5m resolution Digital Surface Models are based on 1.5m resolution SPOT-6 data (Melbourne) and 0.5m WorldView-2 data (Tunis). (GAF AG)

(3)



Flood History, Flood Risk and Associated Infrastructure Exposure

Content and Use

The flood related products provide information about location, intensity and optionally evolution of flood hazards. Thus, they represent key input into identification of exposed assets, population and infrastructure and assessment of flood-related risks.

Heterogeneous historic satellite data from archives could be utilized for detection of flood events in the past. Based on data analysis, minimum and maximum inundation extent for a given period and in combination with precise digital terrain model water depth can be calculated.

Flood risk maps are produced by combination of flood hazard maps with maps of assets (land cover/land use at building block level, buildings, and infrastructure elements). If information on building type, material, floors, population or monetary value of built-up areas are available, vulnerability of exposed assets to floods can be quantified. Using the flood intensity of detected or modelled flood hazard (which is represented usually by inundation depth) the flood risk can also be estimated. Such information represents key inputs into Flood Risk Mitigation plans and evacuation scenarios at municipal or regional level.

Resolution, Availability and Frequency

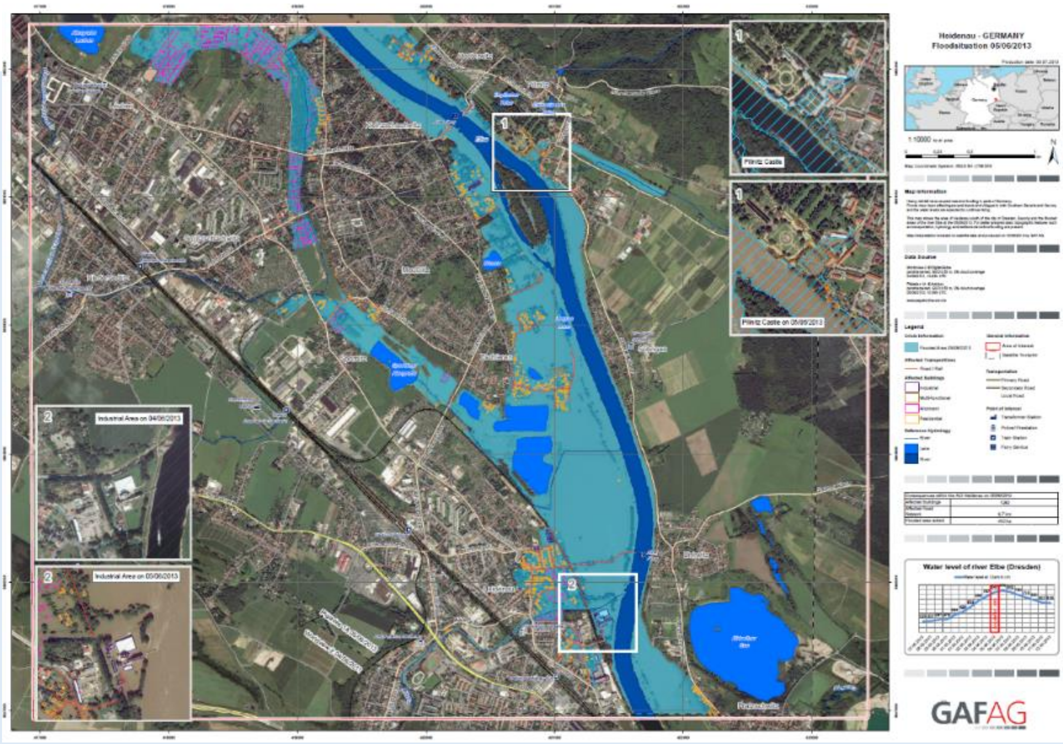
The update frequency of the product strongly depends on acquisition capabilities of the satellites and evolution of observed flood event. State-of-the-art and weather-independent radar data, with high revisit time periods enable acquisition intervals at even less than a week. Such data facilitate monitoring of evolution of both torrential and long-term (e.g. monsoon related) events.

Hypothetic inundation extent and depth relevant for selected flood recurrent frequency (e.g. 50-yr, 100-yr) could be modelled based on accurate hydro-meteorological records, land cover maps and digital terrain model.

Reliability

The positional accuracy depends on the image resolution and ranges between +/- 2 and 10m.

The thematic (classification) accuracy ranges between 70% and 90%.



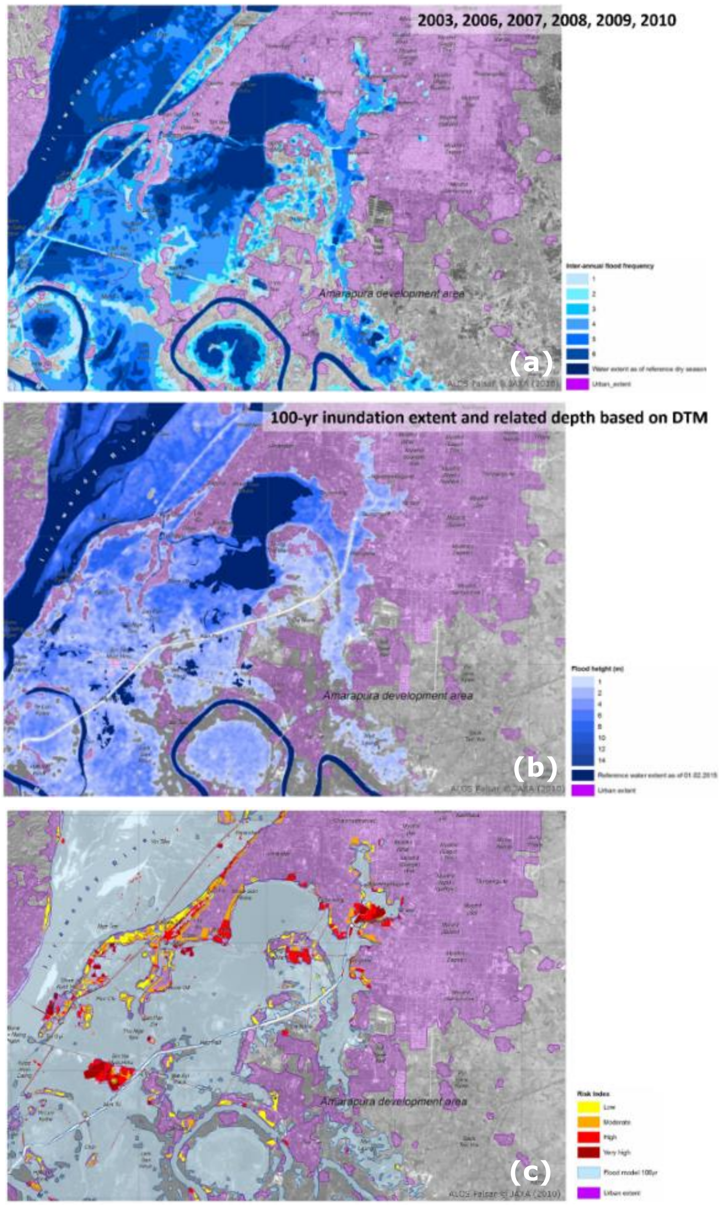
(1)

(1) Flood event detection in Heidenau, Germany on the 6th of May in 2013. (GAF AG)

Benefits

Using current satellite imagery obtained in standard or rapid acquisition mode, the most recent information about extents and impacts of on-going flood emergency could be provided in a matter of days.

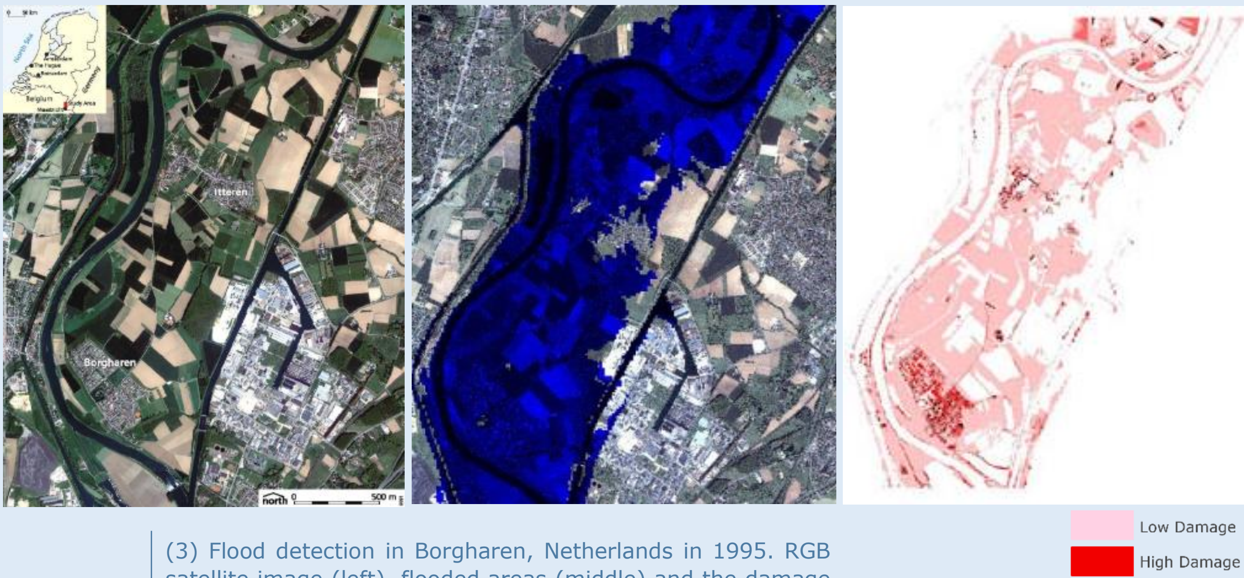
EO imagery analysis is a key tool for monitoring of hazardous flood events posing a risk for urban and peri-urban areas. Hazard exposure maps provide means to identify assets in risk and to quantify proportion of affected infrastructure, population or individual land use/land cover classes. This information is highly valuable for planning and construction of new residential, industrial or commercial development zones at the outskirts of large urban agglomerations, which are potentially exposed to flood hazard. Similarly, risks could be quickly assessed for areas subject to fast and uncontrolled development mostly related to sprawl of informal settlements, where the populations are most vulnerable to impacts of hazard events such as floods.



(2)

(2) Flood history Amarapura, Myanmar from 2003 to 2010 based on archive SAR data analysis (a). 100-yr inundation extent and related depth Amarapura, Myanmar based on DTM (b). Urban extent and building risk index in Amarapura, Myanmar (c). (GISAT)

(3)



(3) Flood detection in Borgharen, Netherlands in 1995. RGB satellite image (left), flooded areas (middle) and the damage caused by the inundation classified into two classes. (NEO)

Landslide Inventory, Landslide Geotechnical Risk and Associated Infrastructure Exposure

Content and Use

In many regions, landslides and associated infrastructure exposure is a common event after heavy rainfall. Optical Very High Resolution data (e.g. Pléiades or Worldview data) provide quick information on location and extent of landslides, furthermore susceptibility maps can be produced by means of a statistical modelling approach.

By merging these susceptibility maps with urban infra-structure and land use data, a risk map can be generated.

This product can assist in the planning of hazard protection measures (e.g. flood protection structures). The maps indicate where the most severe risks arise and the events are most likely to occur. This information is used as a source of orientation in emergency planning.

The maps can also help to demonstrate potential risks to the population and to increase awareness of eventual protective measures.

Resolution, Availability and Frequency

Depending on the accuracy of required ancillary data (e.g. geological database), the spatial resolution can reach about 10 to 20m.

The update frequency of the product is usually once every 3 to 5 years but strongly depends on intensity of land use and infrastructure changes as well as on availability of updated ancillary data.

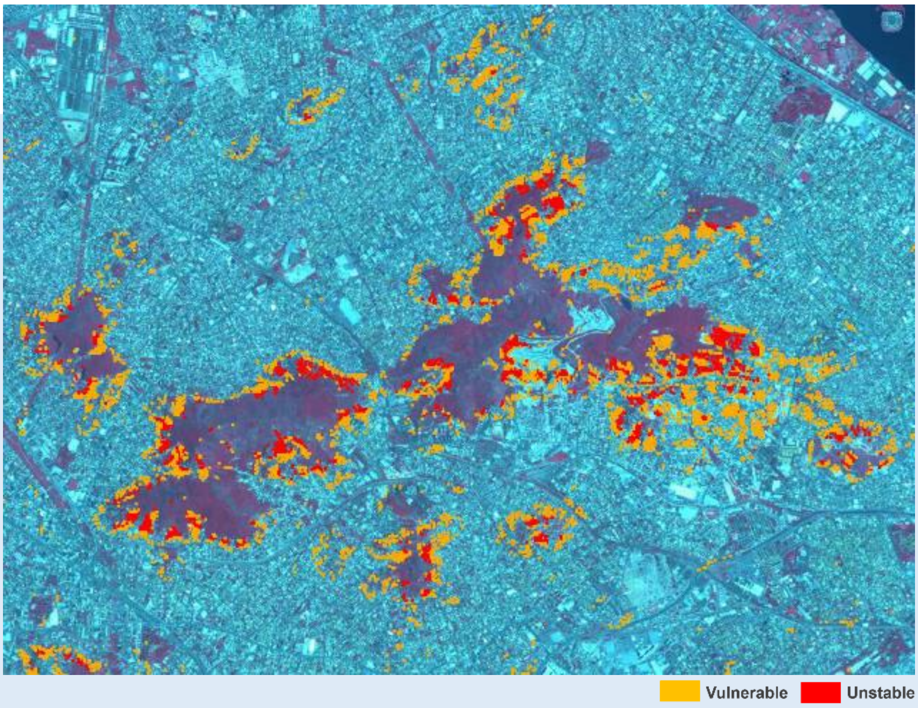
Reliability

The thematic accuracy of the susceptibility classification is highly dependent on input data quality (e.g. geological data-base) but accuracies of 75 to 85% can be achieved.

(1) Landslide Susceptibility Map in favelas and residential areas in Rio de Janeiro in 2011. (NEO)

(2) Landslide event in Rio de Janeiro in 2011 potentially affecting the most vulnerable part of the urban population. (NEO)

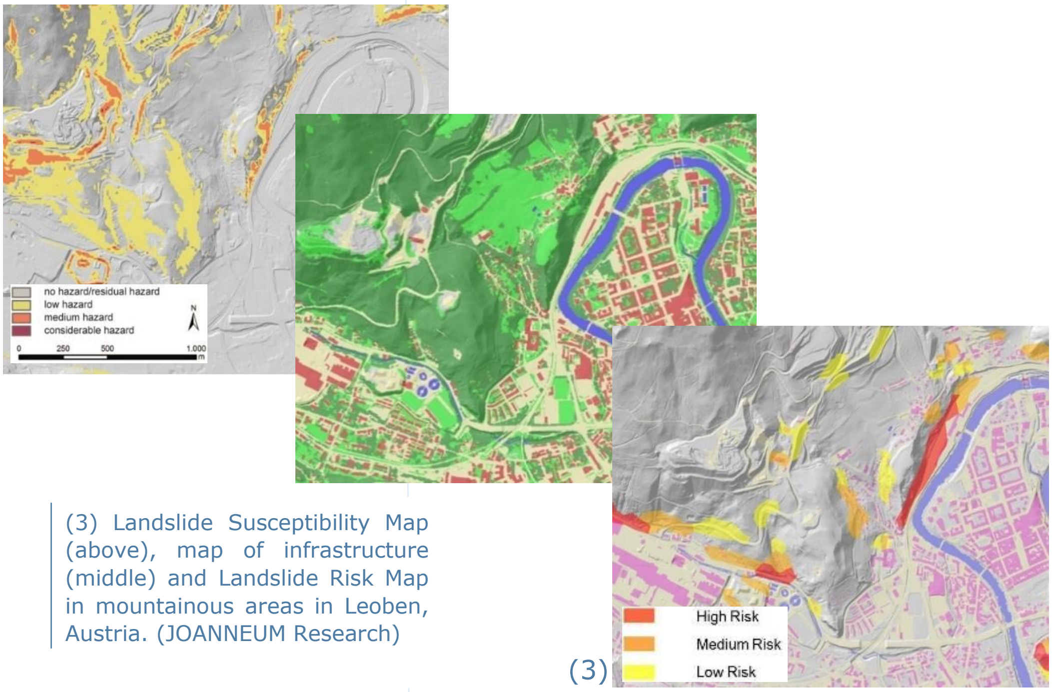
(1)



(2)

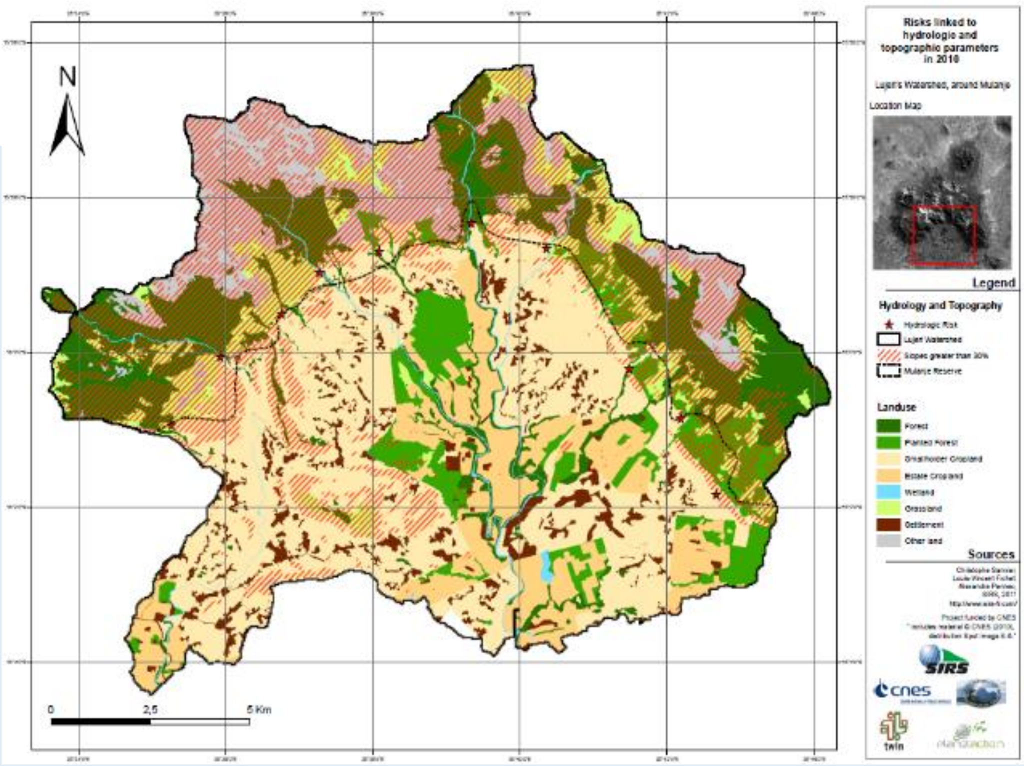
Benefits

The application of EO data enables the definition of hazard risk zones and in development plans and the formulation of building regulations. EO data provides a cost effective and high quality information base for landslide and infrastructure exposure risks.



(3) Landslide Susceptibility Map (above), map of infrastructure (middle) and Landslide Risk Map in mountainous areas in Leoben, Austria. (JOANNEUM Research)

(3)



(4) Landslide prone areas in Malawi in 2010. Map was used to target replanting of trees to prevent future landslide events. (SIRS)

(4)

Urban Terrain/Infrastructure Motion

Content and Use

In densely populated urban regions, areas of subsidence pose a threat to humans and can also cause costly damages to buildings and infrastructure. Such subsidence effects are mostly associated with underground mining activities, extraction of petroleum, brine or groundwater. The increased density of high-rise buildings as a result of population growth further adds to the risk in two different ways. Skyscrapers with their enormous weight increase pressure on the ground; additionally more people can be affected as the population density is much higher in such buildings than in smaller ones. China for example, has over 50 cities affected by subsidence with the related consequences. Therefore, accurate and continuous monitoring of potentially affected areas is important to reduce the threats and costs as far as possible.

Radar data based products allow for the precise monitoring of vertical surface movements with accuracy in the range of 0.5m. This information can be used to generate detailed maps on surface subsidence and displacements to be used for geotechnical applications. Synthetic Aperture Radar Interferometry (In-SAR) products (as generated e.g. from Sentinel-1) can be used to identify such zones as well as to estimate displacement magnitudes.

The products can be used for:

- Monitoring of critical infrastructure
- Monitoring of buildings
- Earthquake displacement mapping
- Monitoring of underground construction sites
- Monitoring of landslides (early warning)

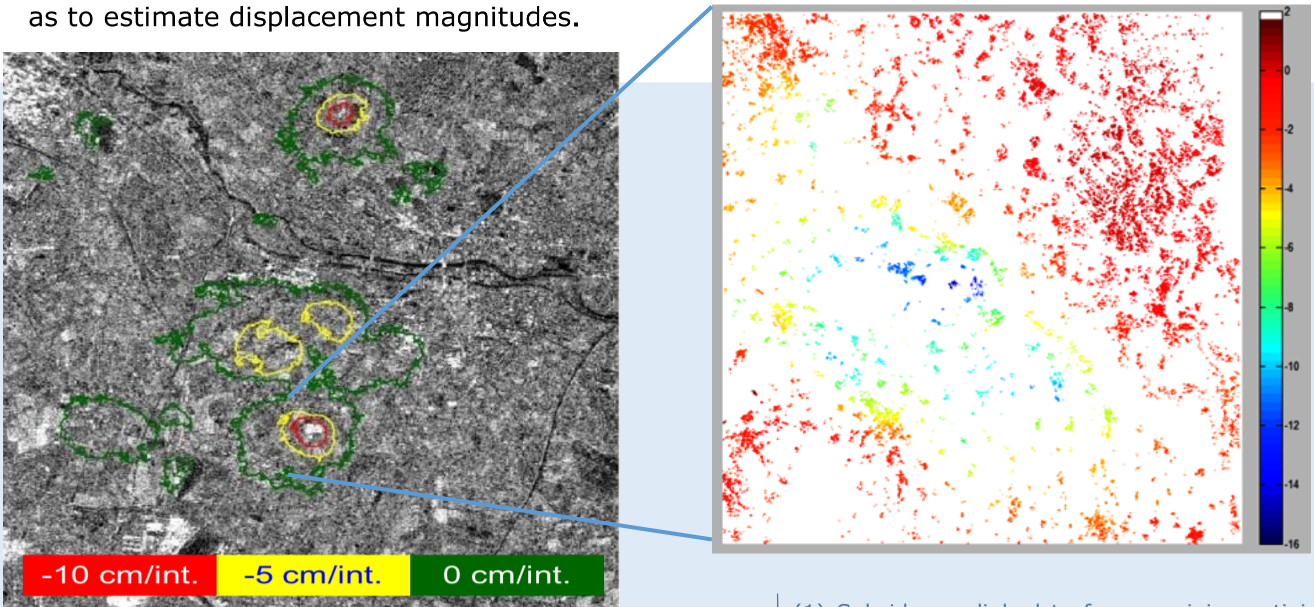
Resolution, Availability and Frequency

In case of using Sentinel-1 data the spatial resolution is approximately 10m. Sentinel-1 provides continuous imagery. The two-satellite constellation of Sentinel-1A, Setinel-1B can deliver a six-day repeat cycle at the equator providing the possibility of continuous monitoring of surface motions.

Reliability

Depending on source imagery, displacement rates between several mm/year and few m/year can be identified.

(1)

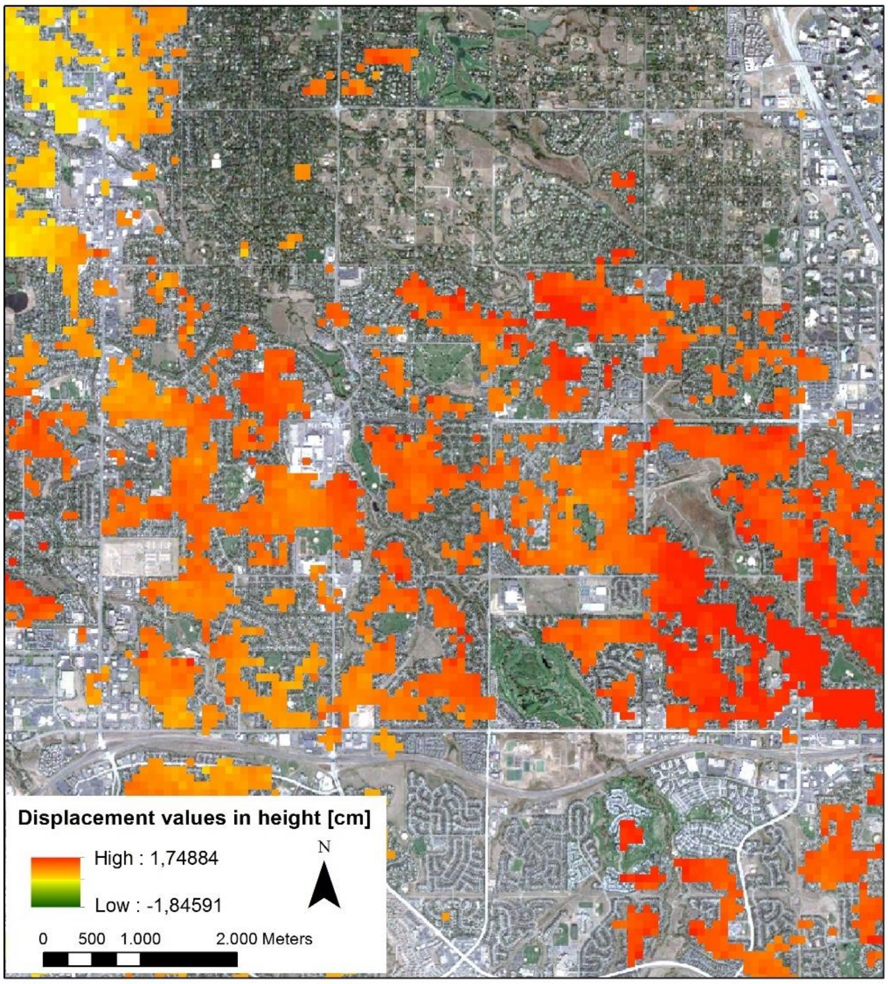


(1) Subsidence, linked to former mining activities, was detected in Dortmund, Germany based on differential SAR interferometry. ERS-1 satellite imagery from 1994 is used for the estimation. (JOANNEUM Research)

Benefits

EO data provides a cost effective and quality assured basis for monitoring of construction and mining sites, definition of hazard zones in development plans and can assist with the formulation of building regulations. The urban terrain product should also be used in conjunction with the Landslide inventory product for improved risk assessments. The motion detection product can especially help in preventing casualties due to ground movements. It can help in preparing Risk Management Plans for evacuating people out of buildings with a high potential to collapse due to subsidence.

(2)



(2) Map showing displacements in Denver between 1992 and 1997 in cm height. This map combines information on geology and provides insight on potential geohazards (JOANNEUM Research)

CONSORTIUM DESCRIPTION

In order to cover the full range of the urban product portfolio, eight companies/institutions have joined their forces to provide a valuable combination of development co-operation experience and EO technical proficiency in production of satellite-based urban geospatial products in international projects.

The Consortium Prime/Lead **GAF AG** from Germany is one of the leading European consulting firms in the field of geo-information offering a broad range of geo-information services and applications, ranging from geo-data procurement (satellite data, DEM, land use and land cover data), image processing and analysis, information processing and software development, to the provision of turn-key technical assistance projects and customized spatial land management and monitoring systems. GAF will especially bring to the project its 30 years of experience in implementing development programmes with WB, KfW/GIZ, EDF, and European Commission. For more information please see *www.gaf.de*. In the EO4SD Urban project, GAF is responsible for the overall management, the strategic developments and the delivery of urban information services.

SIRS is a French remote sensing company and has the lead for the European Urban Atlas programme which has been successfully implemented since 2009. SIRS has years of experience in development co-operation projects in Africa, Asia and South America. For more information please see *www.sirs-fr.com*. SIRS is supporting GAF in the strategic developments and for the delivery of Urban information services.

GISAT is a geo-spatial company in Czech Republic that has project experience in urban mapping and with International Financing Institutions, e.g. Platform for Urban Management and Analysis (PUMA), Urban Atlas, High Resolution Layer Imperviousness. For more information please see *www.gisat.cz*. GISAT is supporting GAF in all strategic developments and in the delivery of urban information services.

EGIS (France) is large multi-disciplinary engineering consultancy company with comprehensive urban expertise. Their Headquarter is in France and they are running Regional offices worldwide. EGIS has a long standing experience in managing high profile Environmental and Social Impact Assessment (ESIA) globally. More information can be found on *www.egis.fr*. EGIS is supporting the Project Team in streamlining the urban information services towards the user needs and in facilitating the stakeholder engagement.

NEO is a company for geo-spatial services in The Netherlands with a strong focus on delivering operational services for Urban development. More information can be found on *www.neo.nl*. With their experience in urban mapping NEO is supporting GAF in the delivery of urban information services.

JOANNEUM Research is the largest non-governmental research institute of Austria, focusing on applied R&D. JOANNEUM has experiences in developing urban products and for clients. For more information please refer to *www.joanneum.at*. JOANNEUM is supporting GAF in the delivery of urban information services.

GISBOX is a Romanian engineering company providing photogrammetric and GIS services; experiences in delivering Urban services (e.g. Urban Atlas). For more information please see *www.gisbox.ro*. GISBOX will support the project in the production of urban information services.

The **German Aerospace Center** (**DLR**) is the National research center for aeronautics and space in Germany and is on the forefront of the research in urban remote sensing. Currently they are coordinating the ESA supported Urban Thematic Exploitation Platform (TEP) and the Global Urban Footprint (GUF) programmes, which are important related initiatives. More information can be found on *www.dlr.de*. DLR is supporting GAF in promoting the utility of urban information services to the user and stakeholder community and is responsible to contribute to the service delivery.

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The **European Space Agency (ESA)** is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world.

ESA is an international organisation with 22 Member States. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

ESA's headquarters are in Paris which is where policies and programmes are decided.

ESA also has sites in a number of European countries, each of which has different responsibilities. ESRIN, the ESA center for Earth Observation is in Frascati, near Rome, Italy.

The current ESA Member States are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxemburg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom. Canada takes part in some projects under a Cooperative agreement.