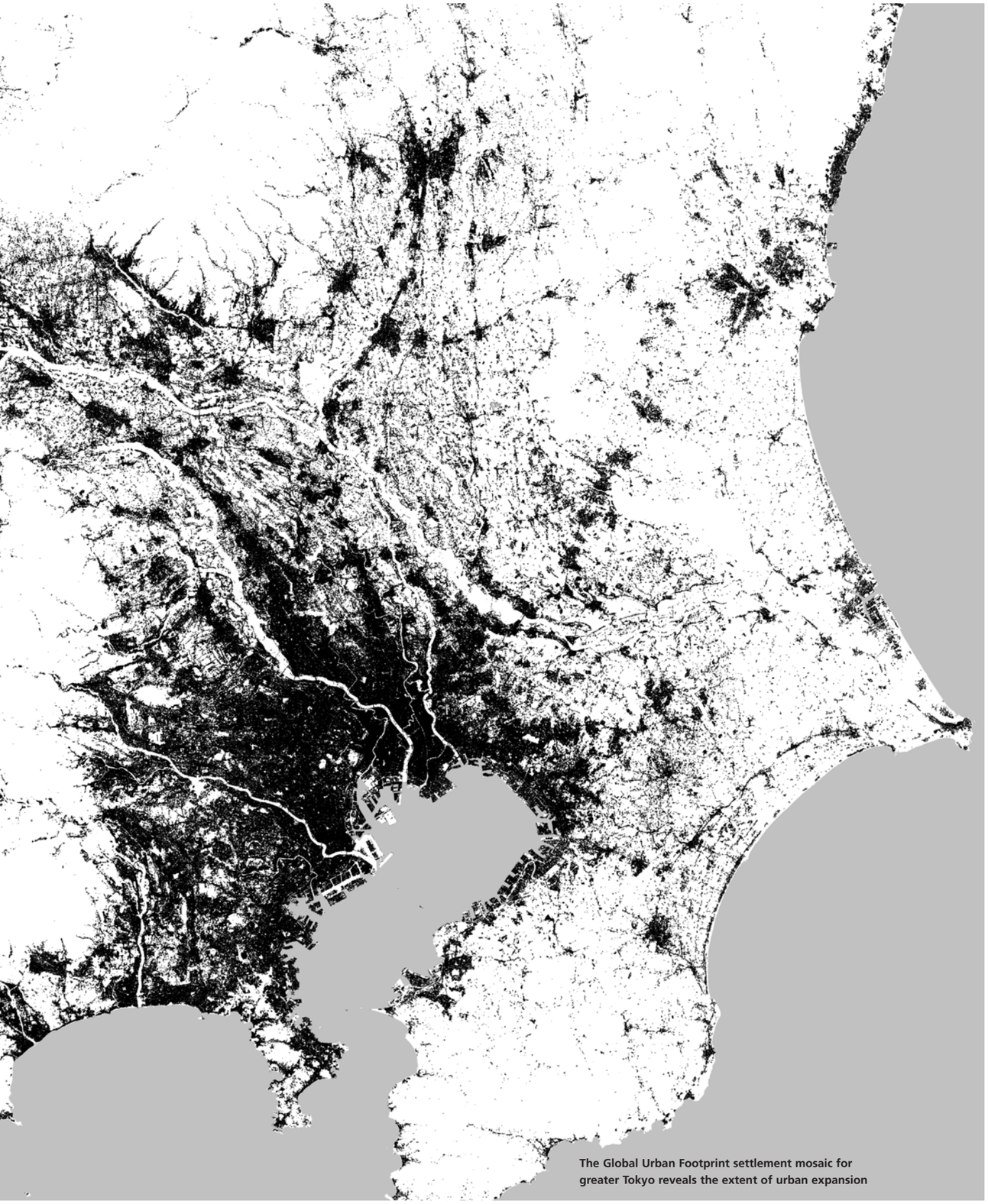


The Global Urban Footprint settlement mosaic for greater Tokyo reveals the extent of urban expansion

Footprints of humankind on the Blue Planet

A large-scale transformation has occurred on Earth, largely ignored in headline stories on the topic of global change – for some years now, the number of people living in urban areas has exceeded that of those living in rural regions. The trend towards urbanisation shows no sign of abating. In particular, cities in Asia and Africa are expanding at a staggering pace. Megacities are springing up in a matter of years and urban sprawls are emerging, spreading across extensive swathes of landscapes that, until recently, had been untouched by development. How can the opportunities that urbanisation presents be put to good use? How can the negative effects of such rapid city growth be mitigated or avoided? This is one of the central challenges that society will face over the coming decades. DLR is using Earth observation data to help create sustainable urban development.

Radar data documents urbanisation with hitherto unseen precision

By Thomas Esch

The future is urban. Today, approximately 7.2 billion people inhabit Earth. By 2050, this number will have risen to nine billion, 70 percent of which will be living in cities. In future, urban areas will account for 90 percent of population growth, 80 percent of increased prosperity and around 60 percent of energy consumption. Urban conurbations will occupy a key role as centres of political, economic and cultural life. They will exemplify the future, defining how the coming generations will live and work.

Managed urban development requires knowledge about how dynamic urban systems interact with the natural and man-made landscape that surrounds them. To what extent do cities damage the environment by consuming land and resources, polluting the air and the water, or by reducing biodiversity? To what extent are cities threatened by natural hazards and climate change? How have urban regions developed in the past, and how should they do so in future?

Urbanisation playing out across the world has regional roots, but it also comes with common drivers and causes. A global view is required to identify what they are. It is here that Earth observation can make a valuable contribution. It helps differentiate between urban and rural settlement forms and to introduce systems of categorisation and delineation. Satellite-based geo-information delivers a current image of progressive urban sprawl, while at the same time documenting its changes over time.

Satellites record settlement areas

Satellites enable continuous mapping of Earth's surface. They allow researchers to record the expanses of cleared forests, lost agricultural land and constructed settlements. But until now, the perception of inhabited areas has lacked a spatially detailed global view; populated areas and those used for infrastructure are frequently hard to distinguish in optical satellite images. Now, scientists at the German Remote Sensing Data Center (DFD), part of the DLR Earth Observation Center (EOC), have succeeded in using a newly developed method to map the world's cities at an unprecedented spatial resolution. A fully automatic image analysis system has used radar data to create a global settlement mosaic at a resolution of 12 metres – the 'Global Urban Footprint'.

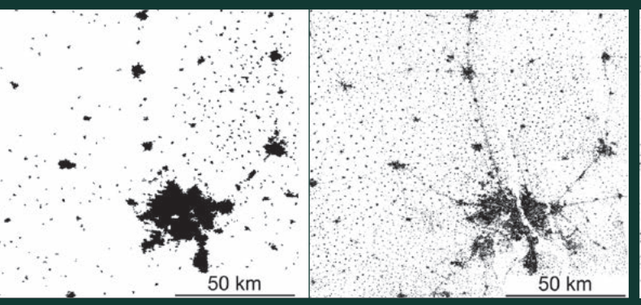
Over 180,000 images acquired by the German radar satellites TerraSAR-X and TanDEM-X between 2010 and 2013 were processed – together with additional data such as digital terrain models – to produce the Global Urban Footprint. In total, the researchers processed over 20 million datasets with a combined volume of 308 terabytes, equivalent to the information contained on roughly 440,000 compact discs. The team applied sophisticated algorithms in a complex decision-making process to assign each of the roughly 50 billion pixels to one of three coverage types: settlements in black; land surface in white; water in grey. This focus on three categories clearly highlights the settlement patterns, improving the ability to analyse and compare them with other built-up areas across the world. Unlike previous approaches, this fully automatic evaluation procedure detects the characteristic vertical structures of human habitations – primarily buildings. In contrast, areas used for infrastructure purposes are not mapped. This is why broad urban canyons or expanses of greenery within the cities are shown as white corridors and patches.

Accurate maps of urban sprawl

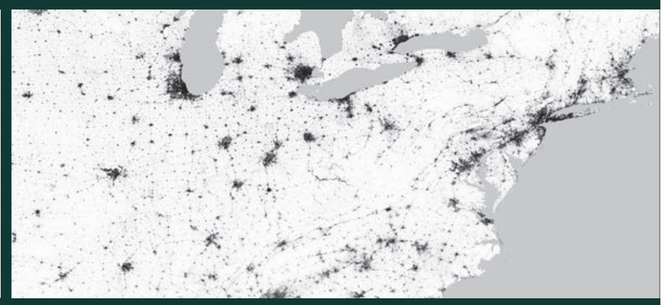
The Global Urban Footprint delivers unparalleled precision. Until now, global analyses have been unable to identify small villages. The single-set satellite systems used offered a maximum resolution of 300 metres, but it is particularly important to consider smaller scale settlements in addition to metropolitan areas. In many cases, villages are symptomatic of a gradual spread in urban development. Disorganised, small-scale settlement is increasingly destroying arable farmland in rural regions and leading to the fragmentation of important natural environments. Biodiversity is reduced and, as the separated areas grow smaller, the environment gradually loses its robustness and capabilities.

Recent estimates have shown that settlements cover between one and three percent of Earth's landmass. The DFD Global Urban Footprint paints a different picture. The proportion

European settlement mosaic derived from the Global Urban Footprint dataset

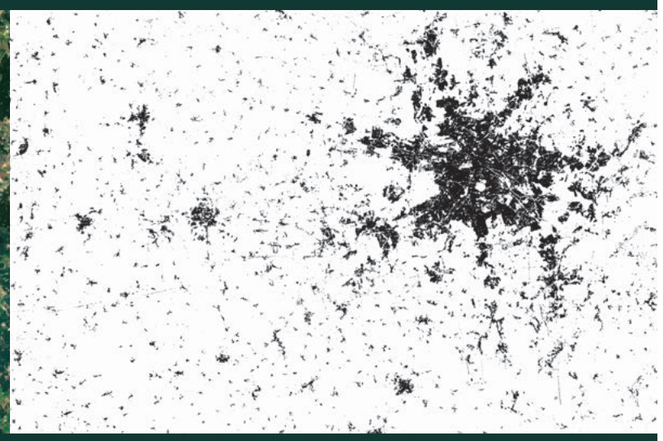


A comparison of the spatial detail between previous global settlement maps (left) and the new Global Urban Footprint data (right) using the example of the Indian megacity Delhi

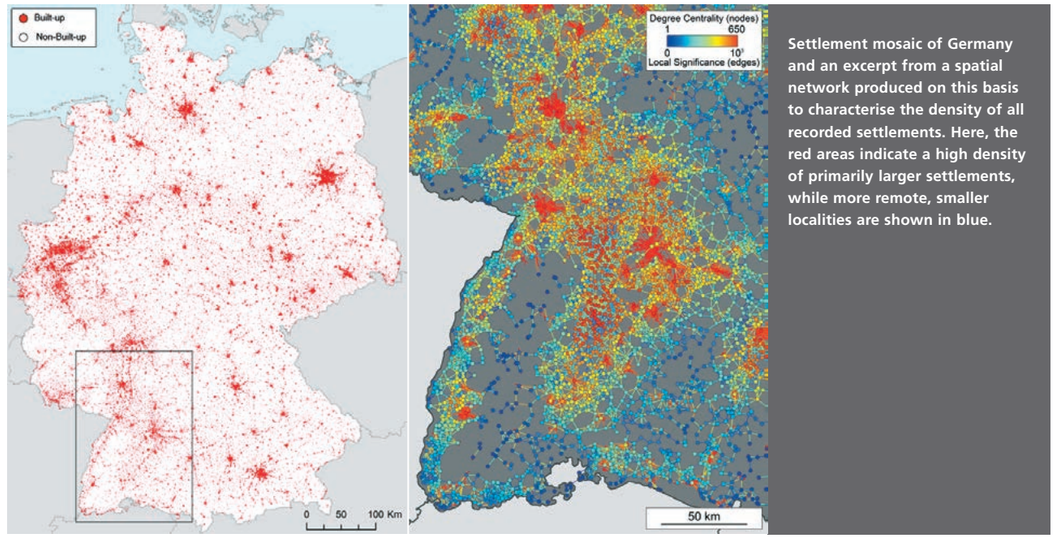


Settlement mosaic showing the northeastern seaboard of the United States with the prominent 'BosWash' conurbation snaking its way from Boston to New York and on to Washington

Comparison – an optical satellite image of Berlin …



… versus the settlement mosaic compiled using Global Urban Footprint data



Settlement mosaic of Germany and an excerpt from a spatial network produced on this basis to characterise the density of all recorded settlements. Here, the red areas indicate a high density of primarily larger settlements, while more remote, smaller localities are shown in blue.

of developed areas has been underestimated in many instances, especially in rural regions. While the percentage differences may be slight, they nevertheless have substantial relevance. Life and work in even the smallest village influences the immediately adjacent environment. A network of small settlements can change the character and ecology of entire areas.

Global diversity of settlement patterns

Settlements reflect the landscape and society. In many cases, they emerged centuries ago in locations offering favourable natural resources or geopolitical advantages – on fertile plains, beside the junctions between important trade routes or along coastlines and rivers. Some of them developed to become growing economic centres, expanding into every available space and precipitating the emergence of satellite cities. In other cases, the burgeoning structures have been more rural in character – a network of hamlets stretching along rice paddies and canals in China, a pattern of villages dotted through cleared forests in southern Germany or the farmyards strung out at regular intervals in the more industrialised agricultural sector of the United States. Hence, settlement patterns and development structures provide a unique and exciting insight into the origins of and cultural history leading to human urbanisation and farmed landscapes. They also show the economic and social trends of more recent times.

It has taken just a few decades for densely packed urban landscapes to emerge in many locations – among them numerous megacities with more than 10 million inhabitants and surrounding regions occupying expanses several hundred kilometres across. Many conurbations blend and merge in these regions, among them Tokyo-Yokohama – with over 37 million inhabitants – and the 'BosWash' belt – a sprawl of cities home to roughly 45 million people, spread across Boston, New York City, Philadelphia, Baltimore and Washington DC.

Precise data and new evaluation methods

The Global Urban Footprint is currently undergoing validation. DFD will make its results available to other researchers in 2015. Examples of its use will include the first comprehensive description of global urbanisation, improved modelling of how cities affect the climate, more precise risk analyses for earthquake and tsunami regions, and assessments of human impact on ecosystems. In addition, DFD has developed a method to quantitatively and qualitatively analyse and compare settlement patterns on a continental and even global scale. Here, all connected settlement areas indicated in the Global Urban Footprint are joined to produce merged objects. Then, for each of these objects, the researchers compute several underlying properties based on size and shape and also compactness, within the overarching settlement structure. The final stage involves connecting all developed areas to produce one spatial network, which is then used as a foundation to efficiently and effectively describe the relationships between the different localities in terms of their centrality and connectivity.

The new dataset from the Global Urban Footprint and the newly developed evaluation method help to acquire a better understanding of the urbanisation phenomenon and hence, in future, to respond appropriately to the immense social challenges of mushrooming cities, population explosion, climate change and the erosion of biodiversity. By improving the quality of spatial analysis and modelling, scientists benefit from the increase in the precision of data relating to settlement structures. Planning agencies and development banks are also important users of these new data and technologies. For instance, uniform data – applicable worldwide – on the location of settlements and including important parameters on their sizes and shapes, as well as their compactness, help with the derivation of important information of a kind urgently needed in infrastructure planning. This is a crucial advantage, especially in remote and underdeveloped regions of Earth, where suitable geographical data are frequently scarce. ●

More information:
DLR.de/guf/en

The Global Urban Footprint Initiative – GUF

Participants: Thomas Esch, Wieke Heldens, Andreas Felbier, Mattia Marconcini, Achim Roth und Julian Zeidler