URBAN GROWTH AND HUMAN CHALLENGES

Towns and cities are increasingly complex and subject to numerous challenges. In response, remote sensing is used on all fronts: it helps to update necessary information, improve diagnostic tools and generate new quality-of-life indicators.

In 2008, our planet reached the inflection point where the global urban population exceeded the rural population. The number of city-dwellers increased from one in ten in 1990 to one in two today. In 1970, Tokyo and New York were the only large cities with more than 10 million inhabitants. Since then, the number of megalopolises has increased tenfold and is continuing to grow, mainly in developing countries. As for cities with more than a million inhabitants, there are hundreds of them, notably in Western Europe, where more than two out of three inhabitants are city-dwellers. Towns and cities are therefore confronted with major sustainability stakes, at the intersection of social cohesion, economic development and protecting the environment. They are at the heart of continuously evolving management, for which remote sensing tools are turning out to be very useful.

BETTER DEFINING URBAN DYNAMICS

Towns and cities are almost constantly undergoing changes. Their external boundaries are incessantly being pushed back and

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The MAMUD, ASIMUD, VALI-URB and BIOHYPE projects have been financed by Stereo II, the Belgian science policy (BELSPO) research programme for Earth observation.
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internally they are subject to successive phases of restructuring neighbourhoods, constructing new buildings and creating green spaces. These changes affect both the human and natural environment. To maintain the inhabitants' quality of life in the face of this process, it is imperative that the local authorities know the causes, the chronology and the effects. Several research projects have studied these parameters based on increasingly detailed spatial and temporal information provided by remote sensing.

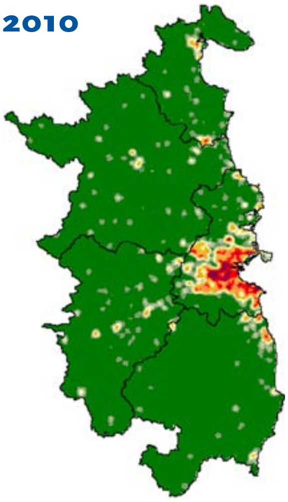
Within this scope, the **MAMUD**-project used high resolution images and medium-resolution time series to measure the impact of urban growth on the structure of the landscape and on residents' accessibility to green areas.

The methods were developed and tested for the cities of Dublin and Istanbul. Both have indeed been subject to considerable expansion: while Istanbul has been continually absorbing the rural exodus for almost half a century, Dublin was boosted by high economic effervescence from the beginning of 1990s up to the financial crisis in 2008.

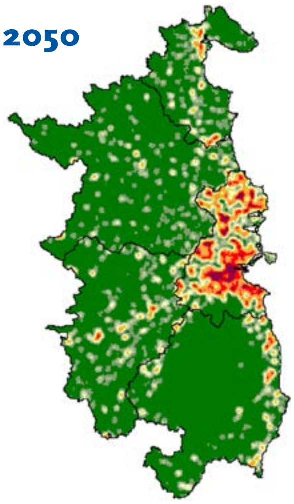
Another project, **VALI-URB**, explored how high and very high resolution images can further improve the characterisation of the urban fabric and the changes it undergoes. The study related specifically to the evolution, in towns and their surrounding area, of built surfaces and vegetation, which both constitute a fragile balance that must constantly be monitored.

Satellite images of Istanbul in 1990 (above: Landsat 5 image with 30-metre resolution) and 2009 (below: SPOT 5 image with 10-metre resolution). On these false colour images the urban expansion is clearly visible in grey-green.

2010



2050



Urbanisation level of Dublin in 2010 and prediction for 2050.

TOWARDS A MORE ACCURATE MODEL

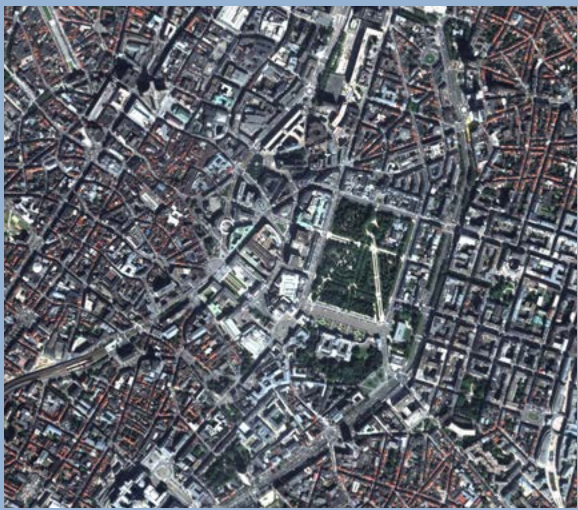
Urban management is often achieved with the help of models that simulate the probable evolution of the situation. The European Commission and its major bodies, such as the European Environment Agency, use them to assess the impact of new directives and recommendations. By refining the extraction of information on urban land use based on satellite data, the **MAMUD** project was able to improve both the existing maps and the MOLAND urban growth model used since 2002.
Besides parameters such as socioeconomic categories, topography and road infrastructure, a model such as this requires detailed spatial information on the occupation of urban spaces. In this instance, satellite images are very useful, even if urban land use can't be directly derived from spectral measurements. A method was therefore developed to deduce urban land use based on urban forms, thanks to maps derived from satellite images that take into account the structure and the density of buildings. This information can then be used to calibrate the MOLAND model, i.e. adjust its parameters to obtain an optimum balance between the planned urban land use and that actually observed by remote sensing.
ASIMUD, a second project, focused on the level of uncertainty of predictions. It depends on uncertainties associated with both the initial parameters and the reference data used for the calibration. The researchers developed an automatic method of calibration that integrates recent urban land use satellite data, at each stage of the simulation procedure. In very simple terms, the team showed that by assimilating certain real data into the simulation process, the model becomes even more effective: it validates the confirmed data and deletes the rest, thus reducing the level of uncertainty of the whole chain. The algorithm developed was made available to potential users, in the form of scripts (written in Python scripting language) under an Open Source licence. These advances are particularly beneficial to the *RuimteModel Vlaanderen*, an urban land use model used as a tool to help decision-making in several Flemish organisations (*Agentschap voor Natuur en Bos, Vlaamse MilieuMaatschappij, Instituut voor Natuur- en Bosonderzoek*).

IMPERMEABLE PIXELS

The wide-scale **MAMUD** project also explored the impact of urban growth on hydrology. The construction of buildings or urban facilities (car parks, asphalted roads, etc.) significantly reduces soil permeability. This massive soil sealing restricts normal rainwater infiltration and accelerates runoff, which increases and exacerbates the risk of flooding in the case of very bad weather. Crossed by three rivers, the city of Dublin often suffers such episodes that endanger its inhabitants and cause major material damage.

In the north of the city, the river basin of the Tolka, which is particularly vulnerable, served as a study area. Assisted by Dublin City Council and Trinity College, the researchers were able to establish maps detailing the runoff coefficient in the river basin for 1988 and 2001, based on satellite image time series. Their comparison highlighted the significant increase in impermeable surfaces, with a high coefficient, thus giving a good indication of the urbanisation phenomenon during this period. A flood prediction model was developed on this basis. It not only takes into account the rainfall-runoff data, but also the changes in the density of the different types of land use (residential, commercial, industrial, recreational, etc.). For the authorities, such tools help guide development policies and decisions towards safer choices.

Pléiades, new possibilities for urban mapping



Shortly after their launch, the Pléiades satellites started providing images that could be directly used in numerous research projects. Launched in December 2011 and 2012 respectively, the twin Pléiades 1A and 1B satellites form a new generation constellation that completes the services offered by the SPOT satellites. In orbit at an altitude of 694 kilometres, the Pléiades satellites can take up to 1,000 shots a day with a daily revisit capability. Light and agile, they are capable of turning on themselves to vary the viewing angles, allowing them to acquire stereoscopic images, which helps measure terrain elevation. While they have a narrower field of vision than SPOT satellites, their spatial resolution is only 50 centimetres, which means they can really zoom into the observed areas. Precision, repetitiveness and stereoscopy: Pléiades images have all the assets to map the urban fabric, which is particularly heterogeneous and subject to frequent changes.

The Pléiades satellites were developed under the responsibility of the CNES, the French Space Agency, but among the programme's partner countries, Belgium holds an important place. In return for this participation, the Federal Science Policy can offer a quota of images at preferential rates to users established in Belgium who are involved in a public service mission, to accomplish tasks within the framework of this mission and for non-market services. It has therefore set up a distribution and archiving system for Pléiades data, called the Belgian Pléiades Archive.

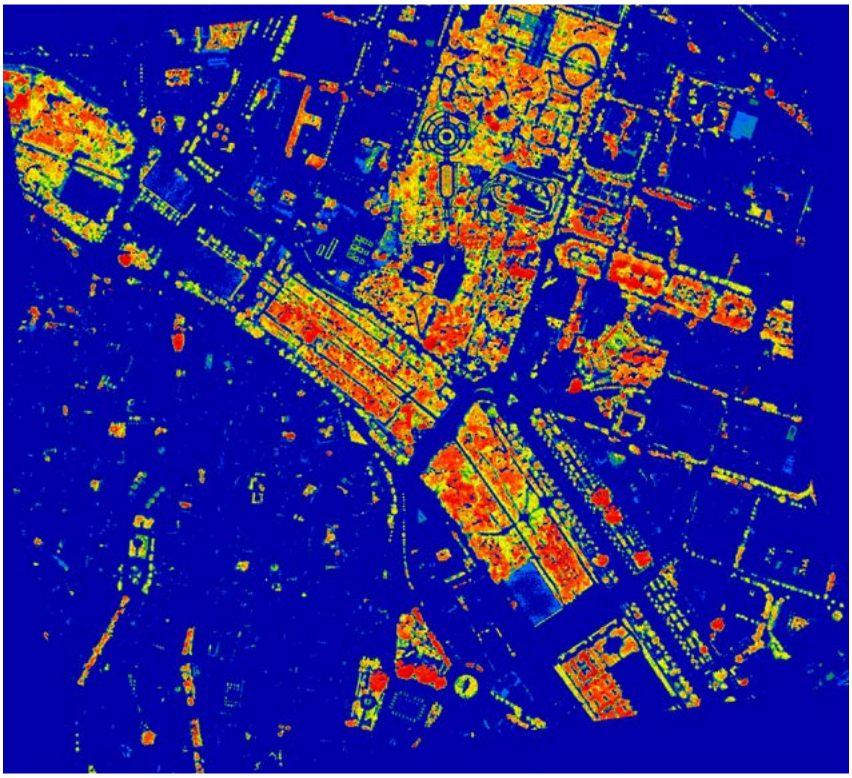
To find out more, visit the Belgian Pléiades Archive portal at *pleiades.belspo.be*.

A GREEN NETWORK WITHOUT ANY TEARS

While land planning requires good tools to aid decision-making, the same is true for the closely linked environmental policies. Adhering to the collective "green" and sustainable management efforts, towns and cities are committed to respecting a series of local and European enforcements (Habitats Directive, Pan-European Biological and Landscape Diversity Strategy, etc.). For instance, the Brussels Region is keen to preserve and maintain the green network that criss-crosses the city. In the urban environment, green spaces fulfil many functions: they regulate pollution and drainage, they provide a green lung for city-dwellers in a highly dense urban fabric and, when they are connected, they ensure the continuity of ecological corridors for animal and plant species allowing them to cross into surrounding green spaces.

Measurement of sun-induced chlorophyll fluorescence using a portable spectrometer.

To obtain updated information on these corridors, the **VALI-URB** project studied how to characterise and list all the green spaces in Brussels: those in the public space but also less accessible elements such as green roofs, private footpaths, gardens or parks within housing blocks. Satellite imaging offers a view of the entire urban surface area, including these out-of-reach green areas. Furthermore, latest generation satellites, such as Pléiades, provide images of vast stretches, with a resolution reaching 50 centimetres, allowing a precise cartographic inventory and an analysis of the changes. By combining the satellite data at different scales with the existing topographical maps, the researchers have developed a consolidated and reproducible method to map ecological corridors. Elaborated in Brussels, the method was transposed to and tested on two medium-sized French cities: Strasbourg and Rennes, in partnership with local universities and certain authorities interested in these results for the management of their area.

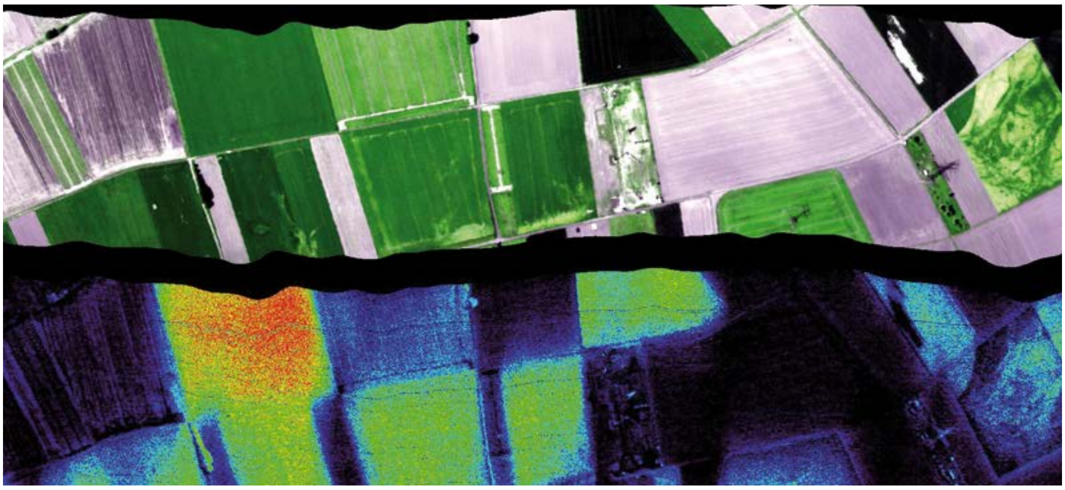


VEGETATION, THE SENTINEL OF AIR QUALITY

Air quality is another great urban challenge. It is influenced locally by the way streets are organised and the amount of traffic passing through. The air quality indexes, to which we are now accustomed, are calculated according to concentrations of several atmospheric pollutants, measured separately (CO_2, NO_2, SO_2, ozone, etc.). In search of a more integrated approach, the **BIOHYPE** project focused on urban vegetation, which is continuously exposed to all pollutants. Polluted foliage, which has accumulated the various substances throughout its growth season, doesn't reflect the light in exactly the same way as healthy, unstressed foliage. Its observation by remote sensing could therefore be a good indicator of the level of pollution, just like canaries used in coal mines would sound the alarm of a lack of oxygen by suffocating.

Vegetation index values (based on hyperspectral data) shown in colour help to visualize individual trees in the city of Valencia.

Fluorescence of different vegetation types, as seen by the airborne Hyplant sensor, in the framework of the preparation of ESA's FLEX mission.



THE INDICATOR TO WATCH: FLUORESCENCE

Conducted in collaboration with the University of Valencia in Spain, the project was carried out at two study sites, in the cities of Ghent and Valencia. Four species of trees that are common in Valencia were selected; samples of trees based in areas of heavy traffic were observed and compared with others located in quieter areas.
A complete battery of reflectance measurements were taken either directly in the field, or using an airborne spectrometer. In addition to the reflected sunlight, plants emit a low level of radiation known as chlorophyll fluorescence.

Researchers were able to reveal that the latter actually varied in correlation with the intensity of urban traffic. Initial results therefore tend to show that fluorescence could ultimately become a valuable bio-indicator of pollution, for instance, to guide inhabitant protection policies and to assess the impact of the implemented measures. In fact, the European Space Agency is planning a mission specifically devoted to fluorescence, with the launch of the FLEX (Fluorescence Explorer) satellite.