Measuring And Modelling Urban Dynamics

Impact on Quality of Life and Hydrology

Frank Canters, Tim Van de Voorde and Luca Demarchi
Department of Geography
Vrije Universiteit Brussel
Brussels, Belgium
fcanters@vub.ac.be

Guy Engelen and Hans van der Kwast
Centre for Integrated Environmental Studies (IMS)
Vlaamse Instelling voor Technologisch Onderzoek (VITO)
Mol, Belgium
guy.engelen@vito.be

Okke Batelaan and Jef Dams
Department of Hydrology and Hydraulic Engineering
Vrije Universiteit Brussel
Brussels, Belgium
batelaan@vub.ac.be

Carlo Lavalle
Land Management and Natural Hazards Unit
Joint Research Centre
Ispra, Italy
carlo.lavalle@jrc.it

Yves Cornet and Marc Binard
Unité de Géomatique
Université de Liège
Liège, Belgium
ycornet@ulg.ac.be

Rudi Goossens, Dennis Devriendt and Frederik Tack
Geography Department
Ghent University
Ghent, Belgium
rudi.goossens@ugent.be

Project web site: http://www.mamud.be

Research project funded by Belgian Science Policy in the framework of Stereo II

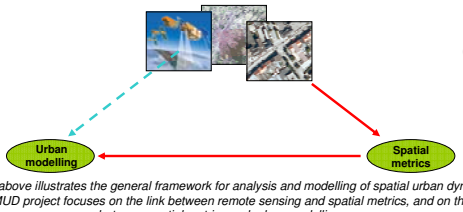
Overview of objectives and methods

Introduction

The world is urbanising at an increasing pace. Urban growth affects both the human and natural environment and calls for effective urban management. This in turn requires reliable and sufficiently detailed information on the urban environment and its dynamics, including an understanding of urban change processes. The MAMUD project will investigate how earth observation can contribute to a better monitoring, modelling and understanding of the urban and suburban environment. Analysing changes in urban land use is a key element in studying urban dynamics. Opposed to land cover, which refers to the physical properties of the earth's surface, land use is tied to socio-economic activities and cannot be directly inferred from spectral information. Previous studies, however, have demonstrated a relationship between the spatial structure of the built-up environment and its functional characteristics. A rather novel approach in this research area is to describe urban form and structure by means of *spatial metrics*. Spatial metrics describe various properties of the spatial heterogeneity and configuration of land cover in a given area. One of the aims of this project is to examine how spatial metrics derived from satellite imagery may complement existing land-use maps to calibrate and validate urban growth models. Spatio-temporal change in land-cover gradients,land use and 3D structure, obtained through analysis of time series of remotely sensed imagery, as well as future land-use patterns predicted by urban growth modelling, will be used to study demographic as well as environmental impacts of urban dynamics. The project also studies the change of *hydrological characteristics* such as increased urban runoff. In studying the effects of land-use change, hydrologists increasingly discover the possibilities of remote sensing derived information.

"The evidence is compelling. As population growth will be virtually synonymous with urban growth in the coming decades, the focus of efforts at sustainable human settlements development must be on urban areas. Cities are where most of the world's population will live and work, where most economic activity will take place, where most pollution will be generated and most of natural resources consumed, with impacts which will be felt far beyond the city limits."

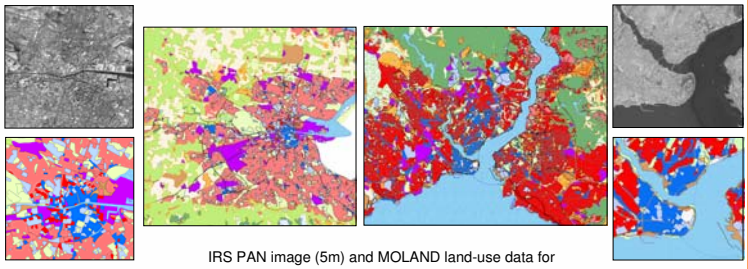
United Nations Centre for Human Settlements, 1996.



The figure above illustrates the general framework for analysis and modelling of spatial urban dynamics. The MAMUD project focuses on the link between remote sensing and spatial metrics, and on the link between spatial metrics and urban modelling.

Study areas

Research will focus on two urban areas in Europe: Dublin and Istanbul. Both are part of a European study called MOLAND (http://moland.jrc.it) of which output will be used in the project.



IRS PAN image (5m) and MOLAND land-use data for Dublin, Ireland (left) and Istanbul, Turkey (Right)

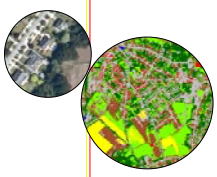
Case study hydrological runoff model

We selected the Tolka river as a case study for the hydrological model because of the strong urbanisation within its basin. This urbanisation is driven by the fast growing city of Dublin, which is located near the south-eastern part of the watershed. The Tolka basin covers an area of approximately 55 km², and has a maximum elevation of 150 m. The river flows in south-eastern direction and discharges into the sea.

In November 2002, a flood in the Tolka basin caused severe property damages in Dublin

Objectives

Extraction of urban land-cover/land-use information and elevation data



Exploiting the potential of multi-angle image acquisition (HiRes data)

- ➔ Developing 3D models with Ikonos image triplet
- ➔ Comparison with 3D models obtained from not explicitly stereoscopic archive imagery
- ➔ To reduce impact of shadows and occluded areas in urban LU/LC classifications
- ➔ To improve labelling of urban objects (e.g. streets versus buildings)

Producing time-series of land-cover gradients (MedRes data)

- ➔ Extracting sub-pixel information on urban land cover (e.g. sub-pixel fractions of built-up area)
- ➔ From time-series of MedRes data with spectral mixture analysis

Extracting historic info on 3D structure of urban areas (HiRes stereo)

- ➔ From high resolution stereoscopic archive imagery (SPOT-5, KFA-1000)
- ➔ Will complement temporal land-cover gradient info with vertical urban dimension

Developing spatial metrics to describe urban form and structure

- ➔ Spatial metrics constitute the link between remote sensing and functional land use
- ➔ They provide an objective description of urban form and dynamics
- ➔ Selection and definition of metrics that describe urban morphological and structural dynamics
- ➔ From high and medium resolution data, which allows examining the impact of spatial resolution
- ➔ Definition of alternative typologies to describe urban form and structure with metrics

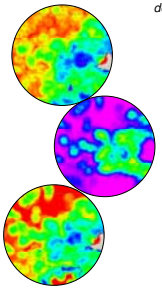
Examining the potential of spatial metrics for urban growth modelling

- ➔ Growth model with Cellular Automata, based on the MOLAND model
- ➔ Can spatial patterns generated by the model also be discerned by the selected metrics?
- ➔ Metrics may complement detailed land-use maps to calibrate spatially-dynamic land-use model
- ➔ Forecasting future land-use and urban growth patterns under alternative policy scenarios

Measuring the impact of urban dynamics

- ➔ Modelling population distribution based on land-cover and elevation metrics
- ➔ Developing quality-of-life indicators to characterise the impact of urban development
- ➔ Assessing the impact of urban development on the rural landscape
- ➔ Urban land-cover and land-use information as input to spatially distributed runoff modelling
- ➔ Sub-pixel imperviousness maps will be used as a driving parameter for changes in runoff
- ➔ Predictive modelling of run-off based on urban growth modeling for flood risk assessment

Methods



This diagram shows how a land-use map may be inferred from remote sensing data.

A land-cover classification can be turned into a land-use map by matching a moving window to a set of pre-defined templates using an adjaceny event matrix. The templates or landscape metric signatures are derived from an existing land-use map (e.g. MOLAND)

The spatial structure of the Moland land-use map (below, top left figure) can be compared to the land-use map derived from remote sensing data through spatial metrics. In the example below fractal dimension is used for this comparison.