Improving spatial information extraction for local and regional decision makers using VHR remotely sensed data (SPIDER)

STEREO Project SR/00/02

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Research teams

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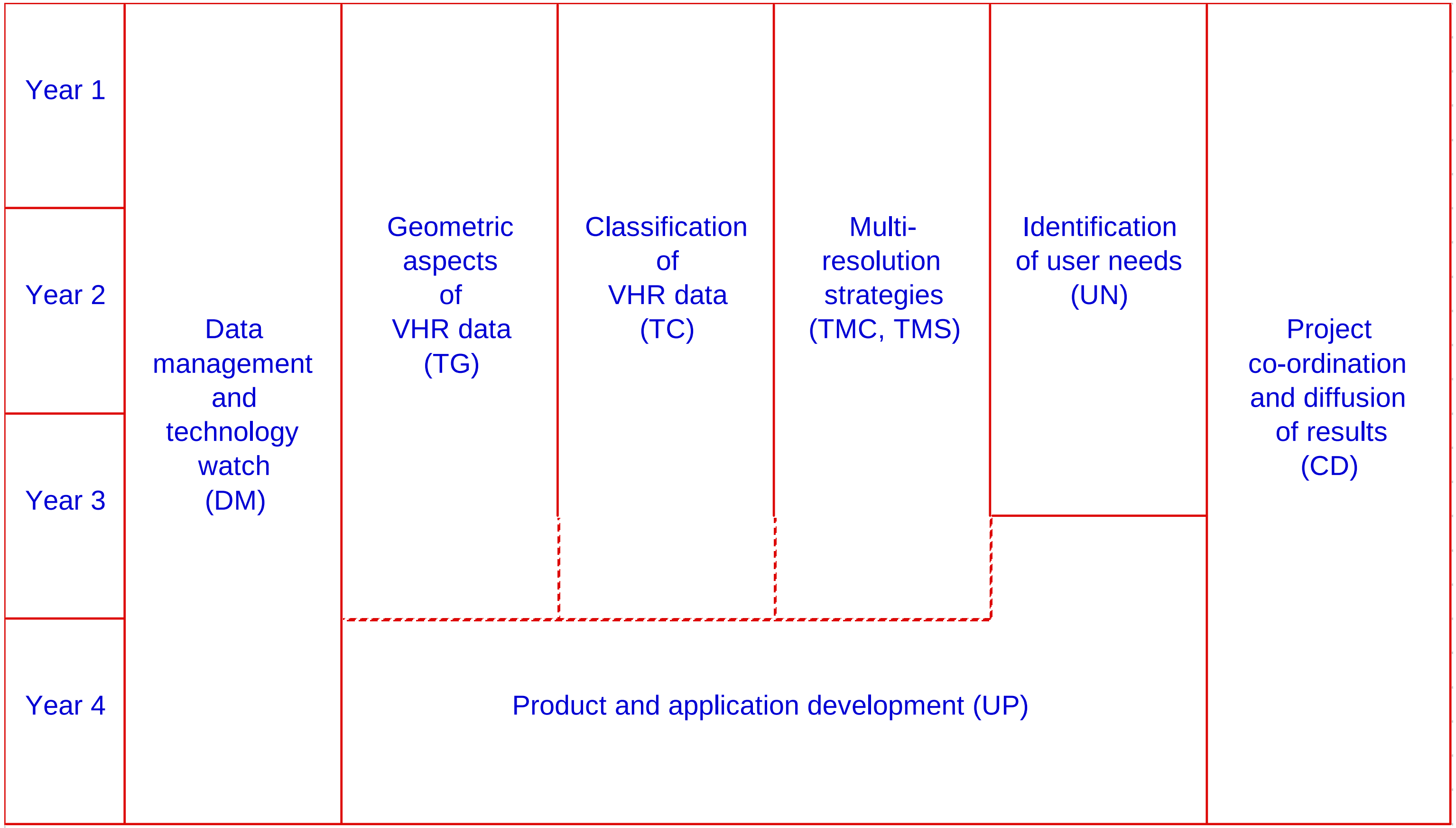
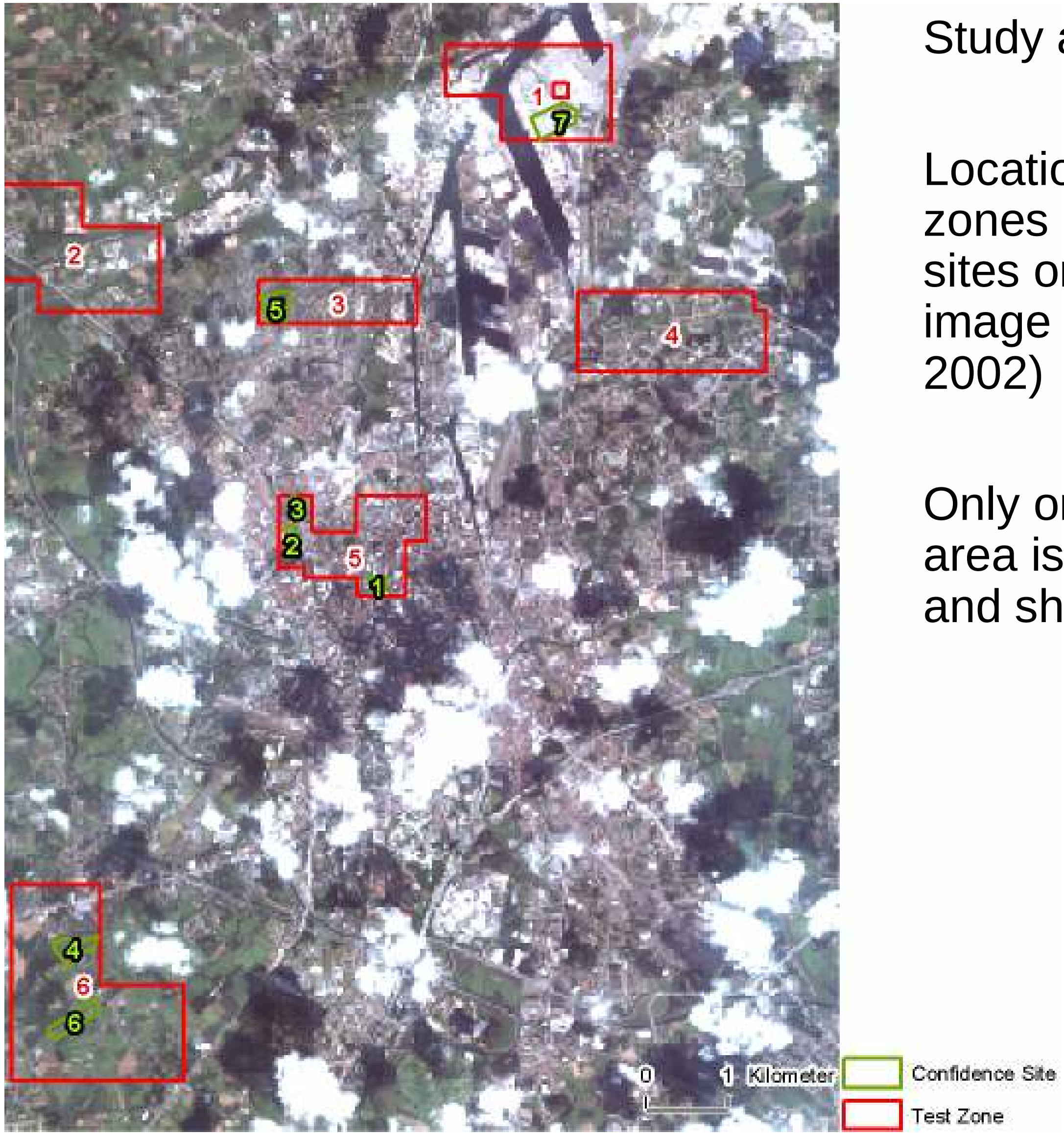
Major objectives

- Investigate how EO-technology can support local and regional decision-making, particularly in Belgium, with emphasis on urban and suburban areas
- Focus on technical and user-oriented issues
- Major objectives:
  - Define optimal methods for improved spatial information extraction from high- and very-high-resolution data
  - Identify useful EO-applications at the level of local and regional decision-making
  - Define and develop value-added products that will support these applications

Overall structure of the project



Study areas, test zones and confidence sites



Study area: Ghent

Location of the test zones and confidence sites on the Quickbird image (23rd August, 2002)

Only one third of the area is free of clouds and shadow

Ghent area: test zones and confidence sites

CS 3 (2.4 ha)
Residential buildings

Test zone 5 (155 ha)

CS2 (1.5 ha)
High density built-up area

CS1 (3 ha)
Old centre

Geometrical aspects of VHR-data processing

- Objective:
  - Evaluate the geometric accuracy of satellite-derived DSMs and ortho-corrected image data in comparison with similar products obtained by large-scale aerial photography

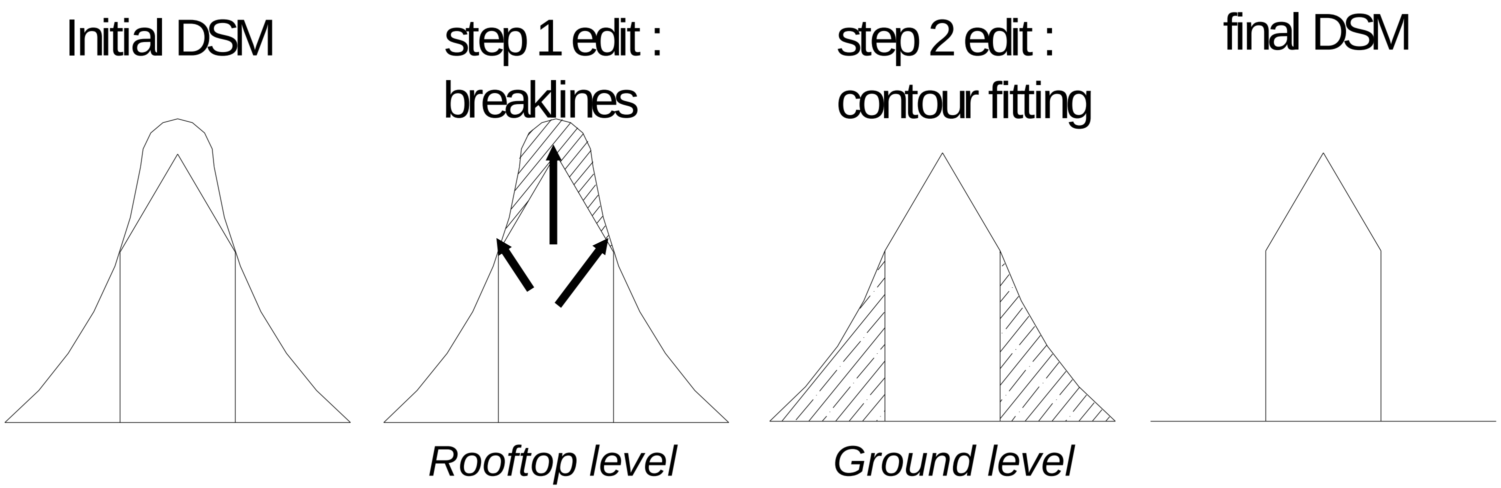
- Topics:
  - Develop reference DSMs from large-scale aerial photography of urban and sub-urban areas
  - Perform ortho-rectification of VHR satellite data based on reference DSMs
  - Define an optimal procedure for the derivation of DSMs and ortho-photoplans from VHR satellite data
  - Study the effect of the oblique viewing angle of VHR data on image displacements caused by building height and relief

Development of reference DSMs

- Collection of GCPs
  - Differential GPS in real-time mode
  - 6 points/stereo-pair
  - Total number of points for Ghent study area: 51
- Reference DSMs for:
  - Test zones
    - Output resolution: 1m
    - Source: aerial photographs 1/12000, resolution 14cm
  - Confidence sites
    - Output resolution: 20cm
    - Source:
      - aerial photographs 1/4000, resolution 8cm
      - aerial photographs 1/12000, resolution 14cm

Development of reference DSMs

- Process of DSM generation



- Step 1 : definition of breaklines
  Rooftop level DSM
- Step 2 : editing of height contours around buildings
  Ground level DSM

DSM editing step 1

DSM editing step 2

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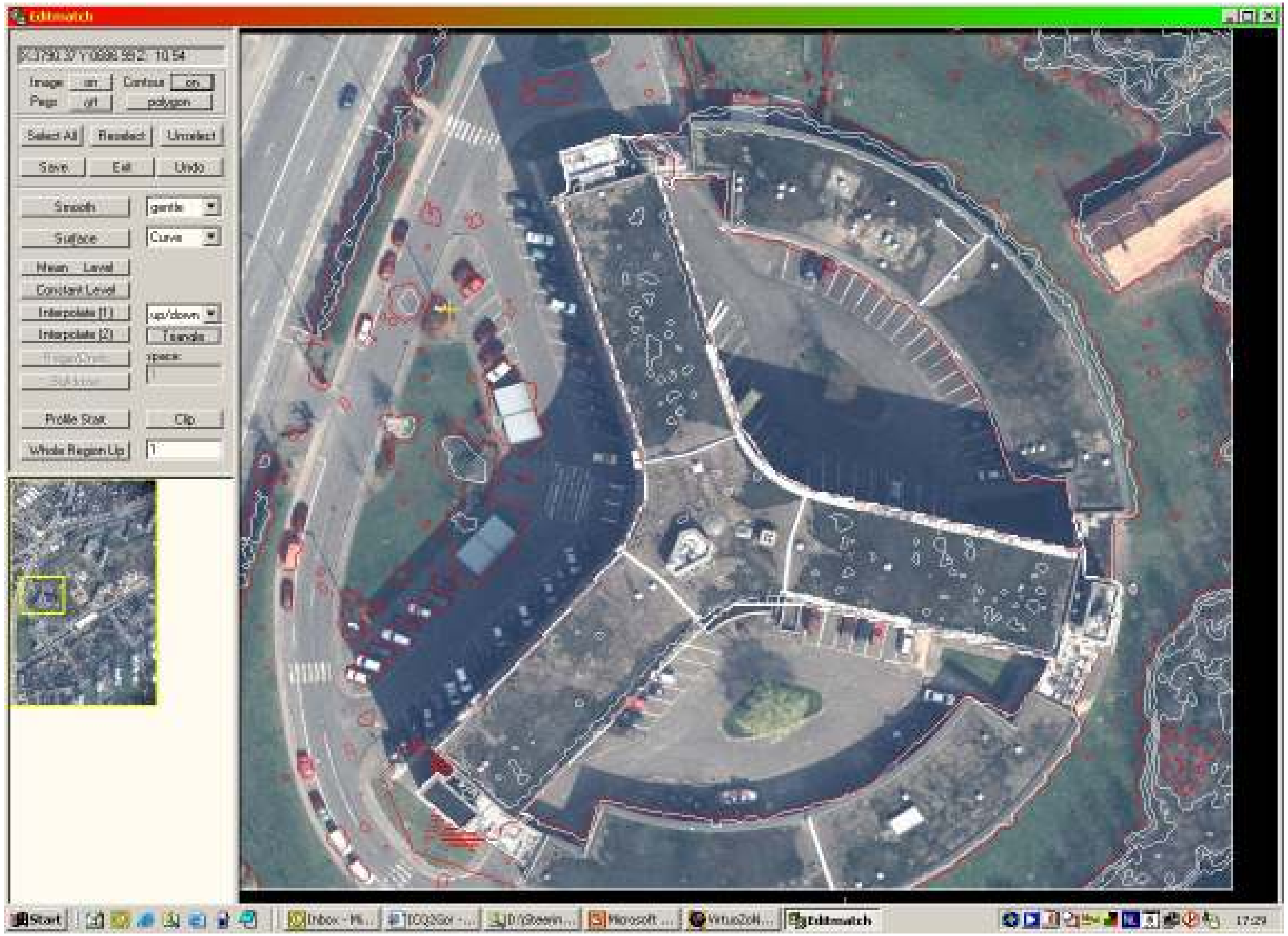

Development of reference DSMs

- Problem in DSM generation:
  - Editing takes about 90% of the time that is needed for DSM creation. The amount of editing depends on:
    - Resolution of output DSM and ortho-photo
    - Height and shape of objects
    - Position of objects in the image (centre or border)

Ortho-rectification of VHR data

- VHR image + Rational Polynomial Coeff. + DSM = ortho-image

The slant effect is corrected: the top of the tower is centred on the longitudinal axis of the church

The slant effect is NOT corrected: the top of the tower is moved with respect to the longitudinal axis of the church

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Classification of VHR data

- Objective:
  - Extract detailed LULC-related information from VHR-data that is useful for local and regional management and planning purposes

- Topics:
  - Evaluate different approaches for VHR urban land-cover classification, using a common reference data set:
    - Probabilistic and non-probabilistic methods
    - Pixel-based and region-based methods
    - Spectral, textural and contextual information
  - Develop strategies to infer land use from land-cover classification results, using rule-based techniques

LULC classification scheme

Land use 1 (LU1)	Land use 2 (LU2)	Land cover (LC)
1. Buildings	1.1 Isolated house	Grey surface
	1.2 Block of houses	Orange/red surface
	1.3 Low building	Green copper
	1.4 High building	Glass or plastic
	1.5 Other	Bare soil
		Water
2. Road and rail network	2.1 Road	Grass
	2.2 Parking	Crops
	2.3 Railway	Shrub and trees
	2.4 Square	Mixed
3. Hydrology	3.1 Water body	
	3.2 Watercourse	
4. Vegetation	4.1 Urban green area	
	4.2 Agriculture	
	4.3 Forest	
5. Miscellaneous	5.1 Sport or recreative area	
	5.2 Graveyard	
	5.3 Construction site	
	5.4 Other	

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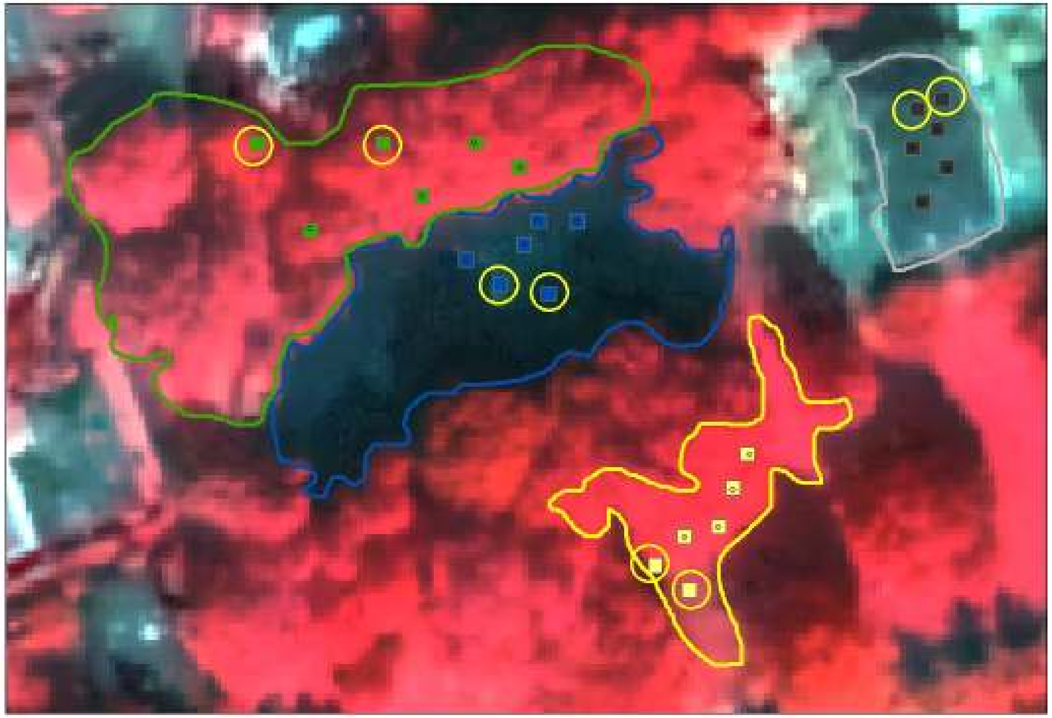
Collection of training and validation data

Choice of « training polygons » on aerial photographs

Selection of training pixels on Quickbird image



Atypical training pixels

Typical training pixels

Grass

Training polygons

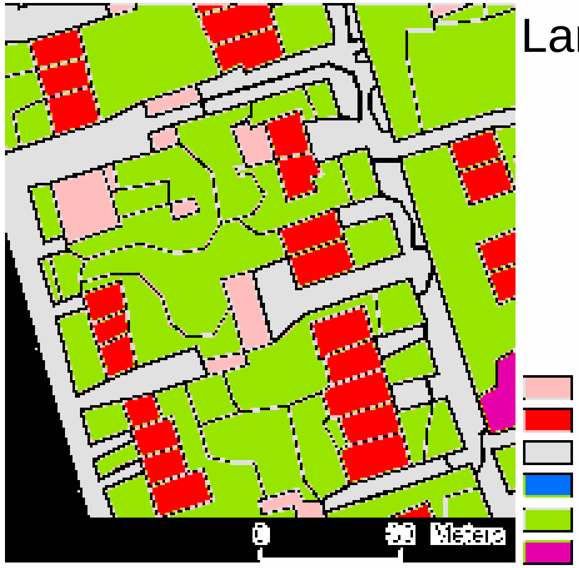
Grass

3X3 training blocks

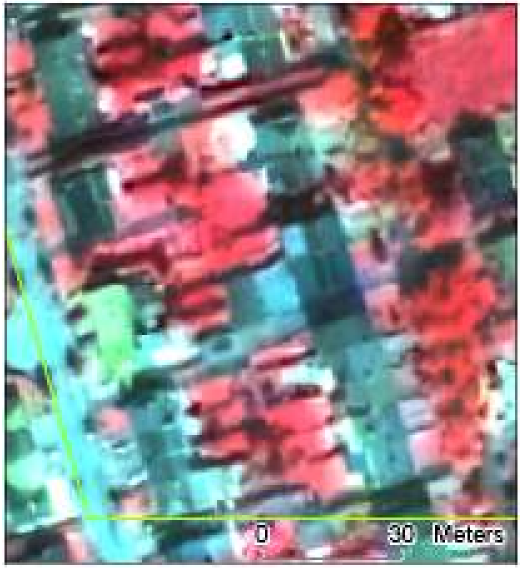
Grass

Visual interpretation of confidence sites

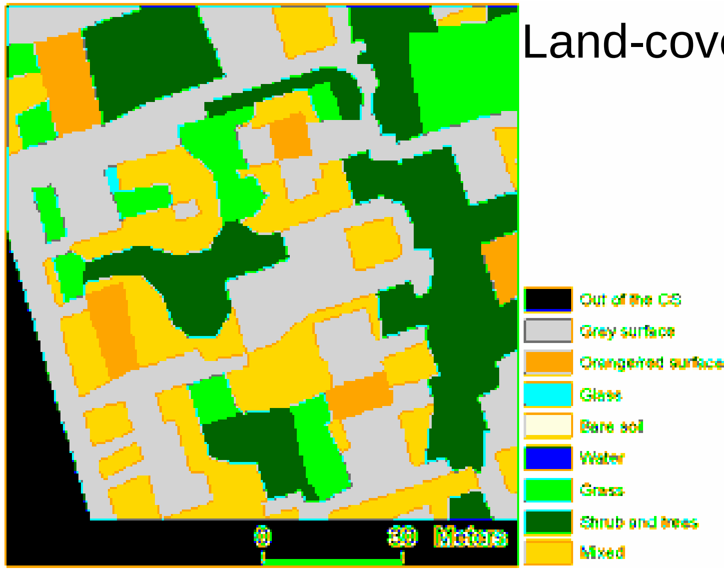
Aerial photograph



Land-use 2



Quickbird image



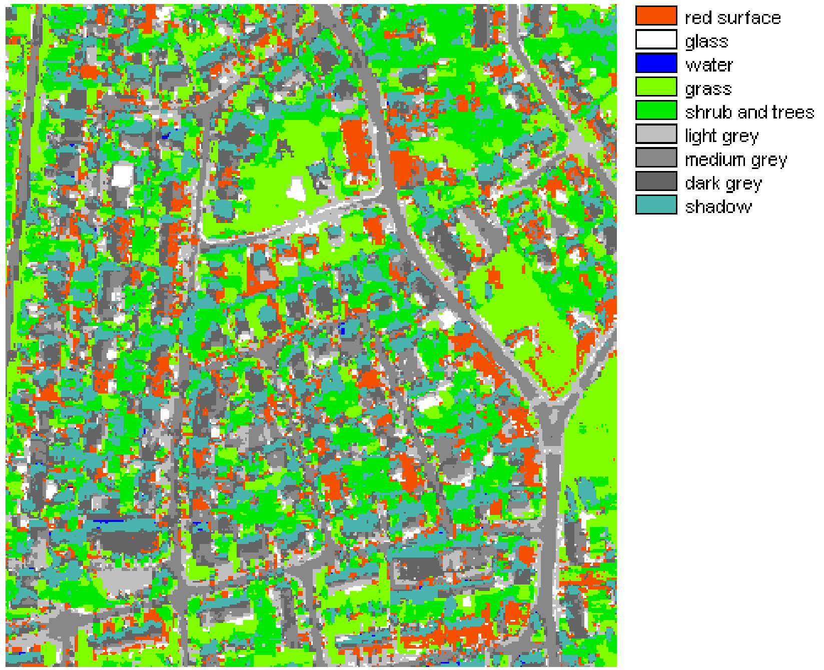
Land-cover

Land-cover classification approach

- Comparison of results obtained with:
  - Different classifiers
    - Maximum-likelihood classification (ML)
    - Neural network classification (NN)
    - Region-based classification (E-cognition)
  - Different classification variables
    - Spectral variables (R, G, B, IR, PAN, NDVI)
    - Spectral + textural variables
      - Measures derived from Haralick co-occurence matrices, calculated for different window sizes (NN)
      - Segment-based texture measures (E-cognition)
  - Different training approaches
    - 4 typical pixels per polygon
    - 4 typical and 2 atypical pixels per polygon
    - 6 blocks (3x3 pixels) per polygon

Pixel-based classification

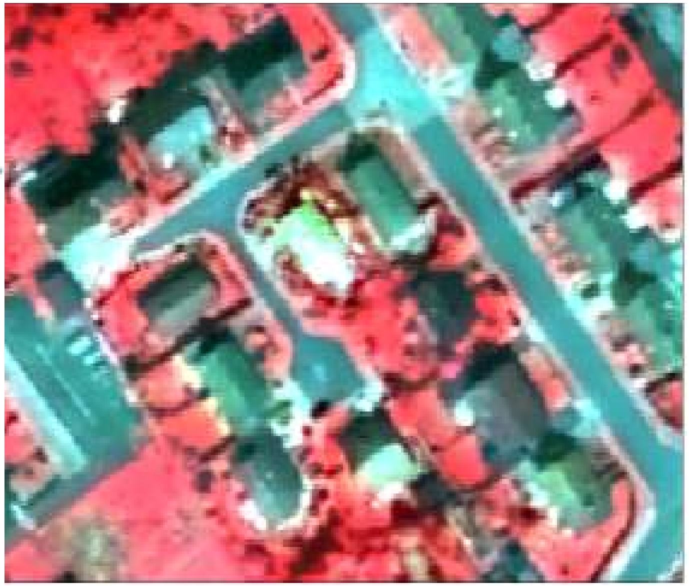
True-color composite

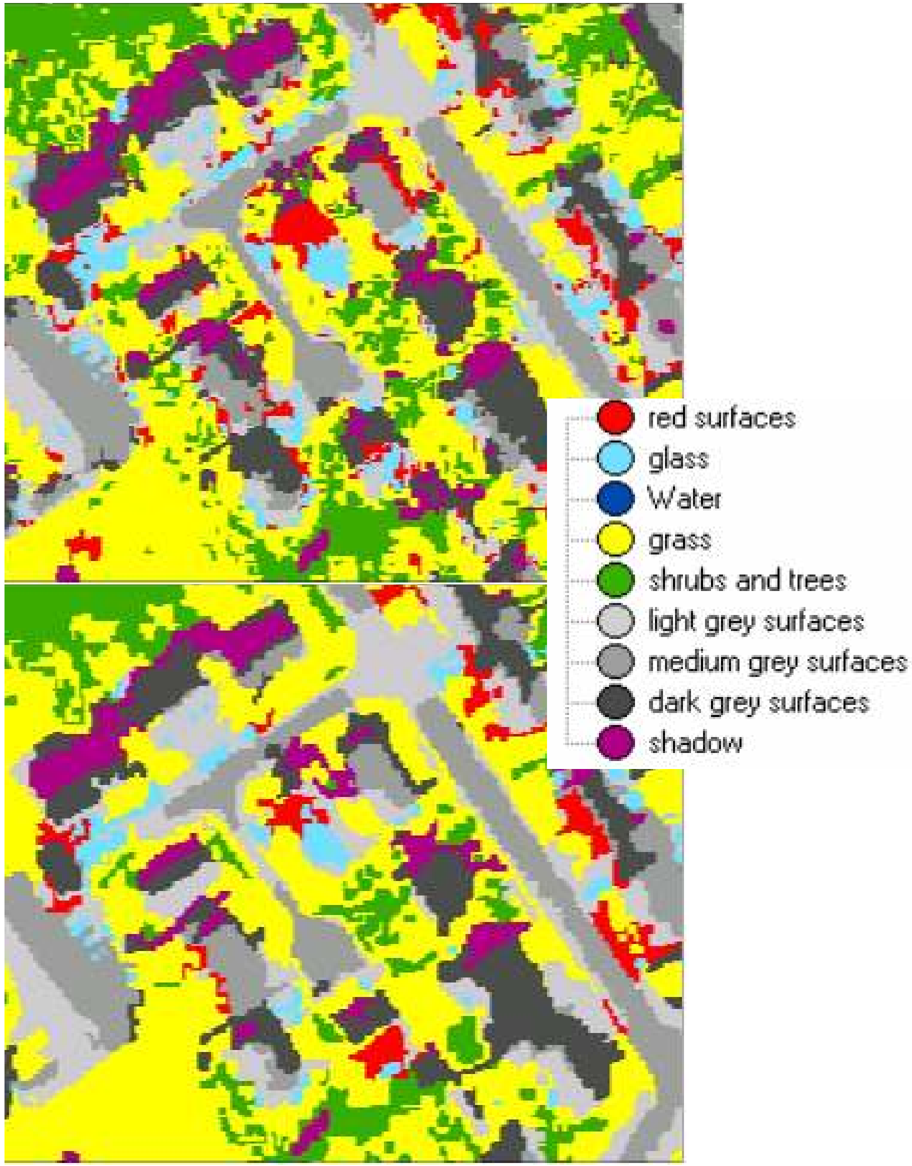


Neural network classification
Best scenario: Kappa = 0.83

Region-based classification

Scale parameter = 4.7
Kappa = 0.80





Scale parameter = 15
Kappa = 0.74

Classification results

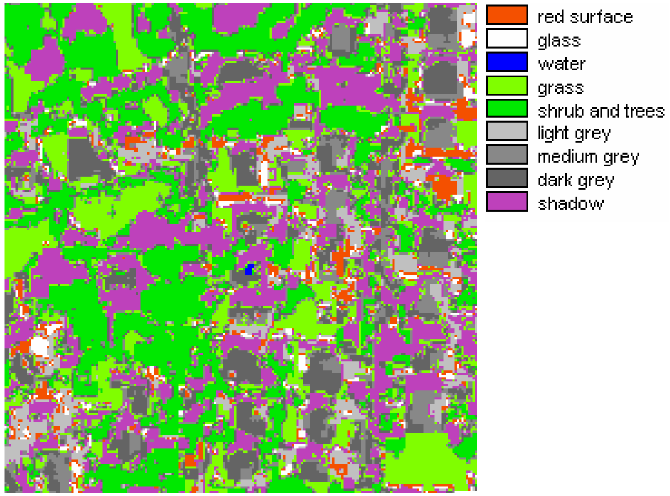
- Different classifiers
  - Differences in overall classification performance for maximum-likelihood, neural network and per-region classification are very small (best Kappa's around 0.80)
- Classification variables
  - Adding the PAN-band to the four spectral bands substantially increases classification performance
  - Adding window-based texture measures in per-pixel classification slightly increases the performance of the classifier (from 0.79 to 0.83 for the best approach)
- Different training approaches
  - Including atypical pixels in the training phase improves the overall accuracy of the classification with a few percent for some classification scenarios
  - The use of 3x3 training blocks does not improve the accuracy of per-pixel classification

From land cover to land use

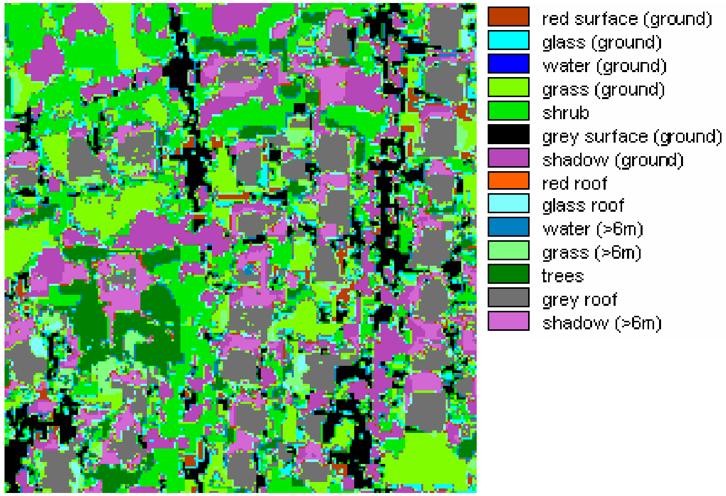
- Two-step approach:
  - Classification of land cover, followed by:
    - Post-classification filtering (per-pixel approach)
    - Aggregation of image segments belonging to the same land-cover class (segmentation-based approach)
  - Inference of land use from land cover:
    - Rule-based classification or grouping of land-cover regions
    - Using:
      - Region-based metrics (area, shape,...)
      - Properties of neighbouring regions
      - Ancillary data, e.g. DSMs, vector maps

Post-classification based on DSM

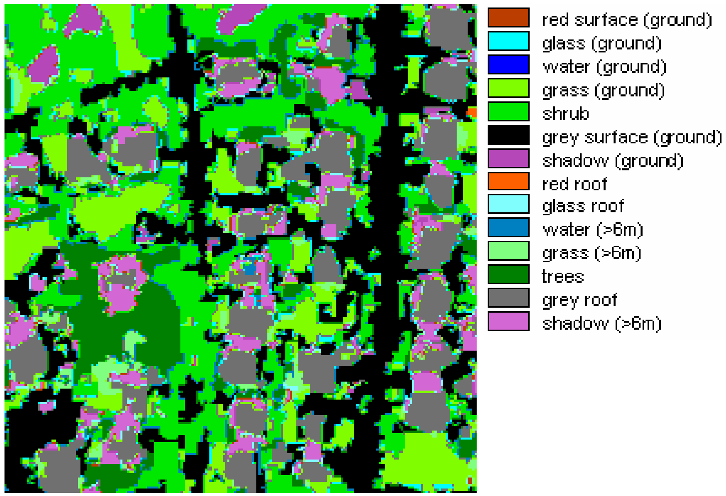
NN-clasification



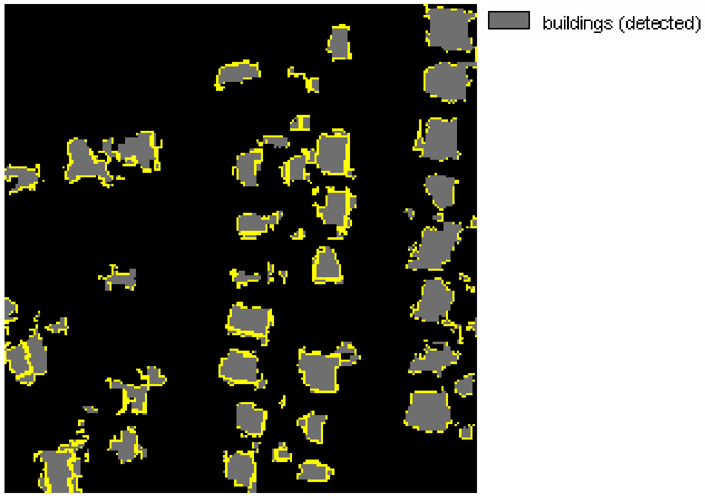
Intersection with DSM



Postclassification (rule-based)



Identification of buildings



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Assessment of GI needs in Belgium

- Objective : assess the GI needs of Belgian local and regional authorities in order to define useful products or applications of HR/VHR data, in an urban or suburban context
- Survey of a carefully selected group of users
  - Approach:
    - Detailed written survey (82 closed questions), followed by in-depth interview to gain more insight into :
      - Use and treatment of geographical data
      - Products/applications based on these data
      - Specific land-use/land-cover information needs
      - Use of satellite data
  - Targets:
    - 20 to 30 key representatives of various local and regional authorities in Flanders, Brussels and the Walloon region

Multi-resolution approaches

- Objective: combine VHR-data with HR-data for cost-effective production of detailed information on land-use/land-cover for extended areas

- Focus on two distinct, yet closely related issues:
  - Sub-pixel classification:
    - Estimation of sub-pixel class proportions for HR-pixels (ETM+), using VHR-data as a source for calibration
  - Sub-pixel mapping:
    - Use of sub-pixel class proportions to predict the spatial distribution of classes at smaller pixel sizes

Methodology

High resolution images

Sub-pixel classification (soft)

Fraction images (high resolution)

Fraction images (high resolution)

Sub-pixel mapping

Hard classification (high to very high resolution)

Sub-pixel mapping

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Land cover 1

32%	100%	40%
12%	40%	16%
0%	0%	0%

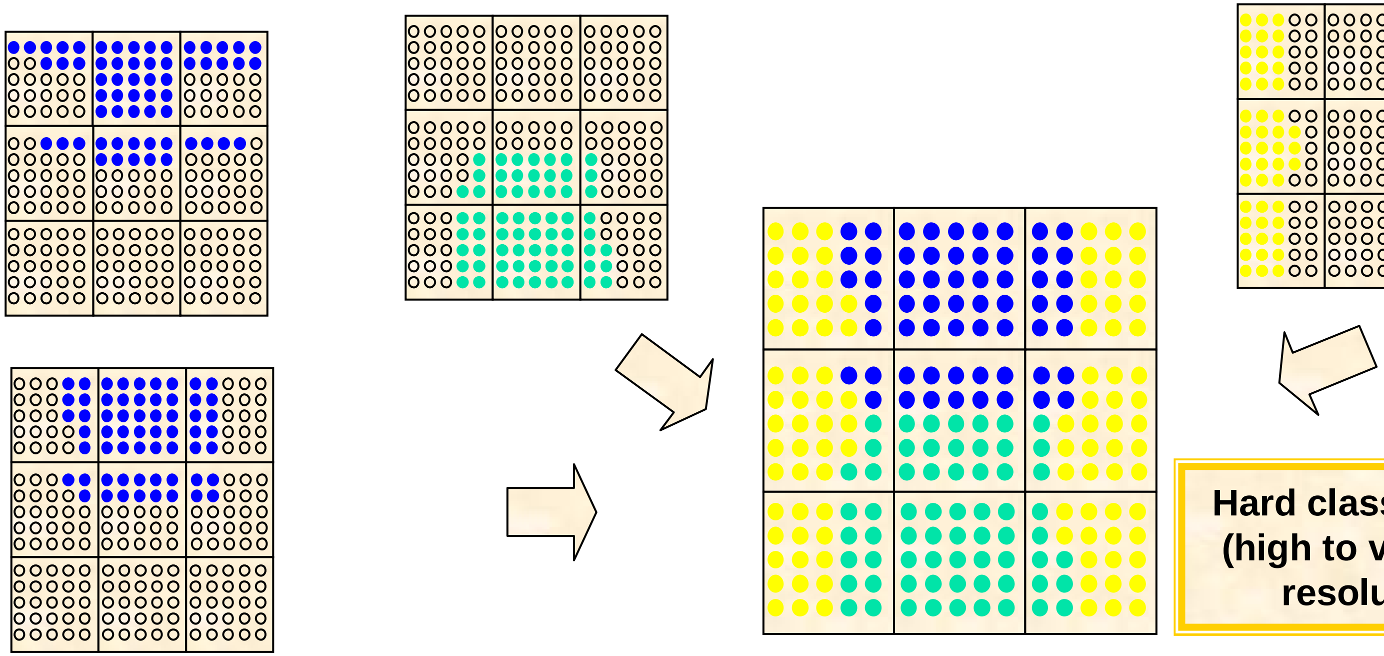
Land cover 2

0%	0%	0%
16%	60%	12%
40%	100%	32%

Soft classification (high resolution)

Land cover 3

68%	0%	60%
62%	0%	72%
60%	0%	68%



Hard classification (high to very high resolution)

Sub-pixel mapping: approaches

- The different techniques:
  - Simplex: solving a set of linear equations
  - Use of Genetic Algorithms to optimize configuration
  - Neural Networks: learning spatial configuration

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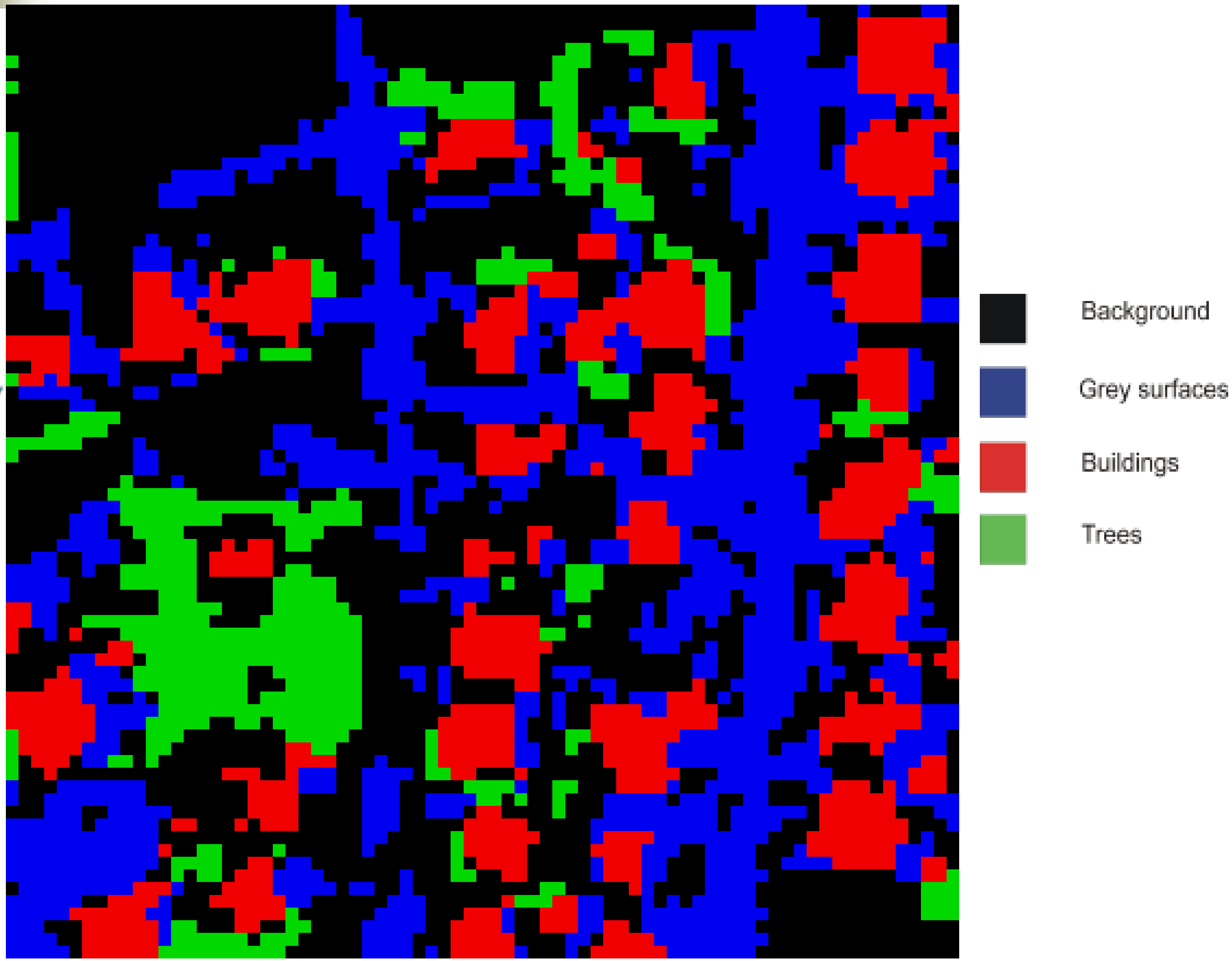
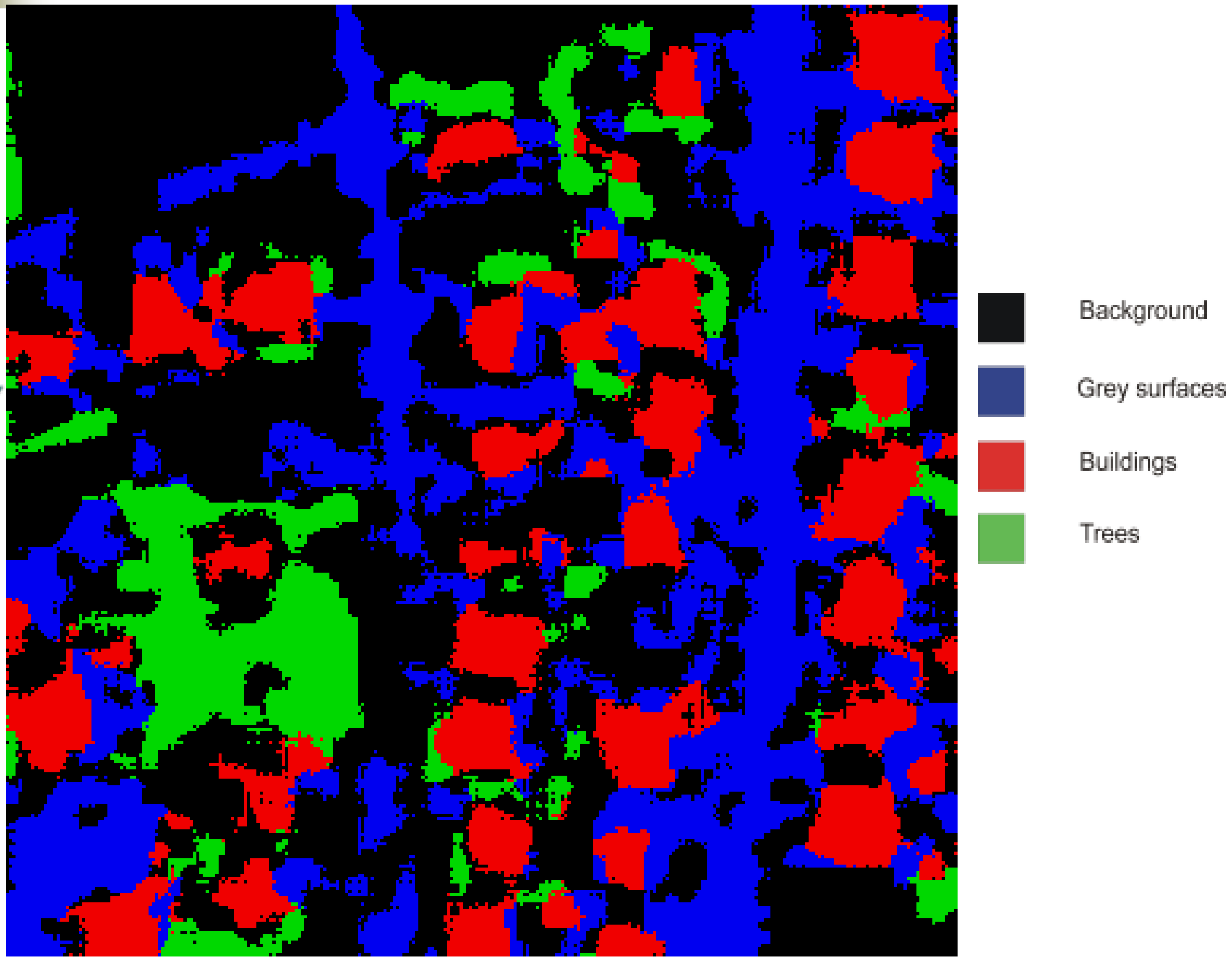
Example: Sub-pixel mapping of degraded VHR-classification on Gent

- Scale = 2
  - Hard classification: Kappa = 0.900
  - Simplex inv. sq. dist. : Kappa = 0.967
- Scale = 4
  - Hard classification: Kappa = 0.813
  - Simplex inv. sq. dist. : Kappa = 0.887
- Scale = 10
  - Hard classification: Kappa = 0.649
  - Simplex inv. sq. dist. : Kappa = 0.707

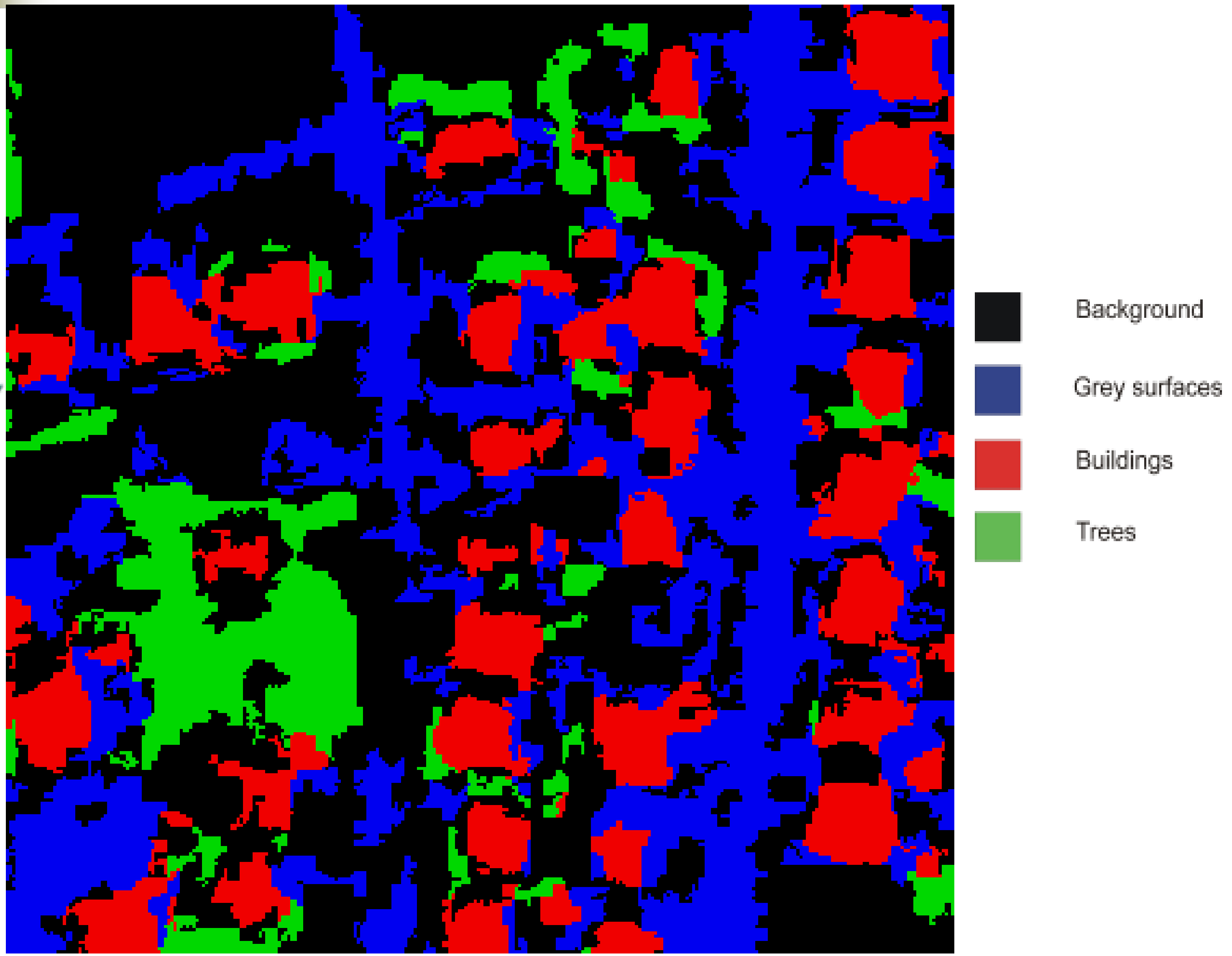
Hard classification, scale 4, resolution 2.44 m



Sub-pixel mapping, scale 4, resolution 0.61 m



Reference image, resolution 0.61 m



Final goal

VHR-classification (QuickBird)

Degradation

Degraded classifications used as reference

Evaluation

Intermediate resolution classification

Sub-pixel mapping

HR sub-pixel classification (Landsat)

- Note: Introduction of extra error due to:
  - Errors in the sub-pixel classification
  - Co-registration errors