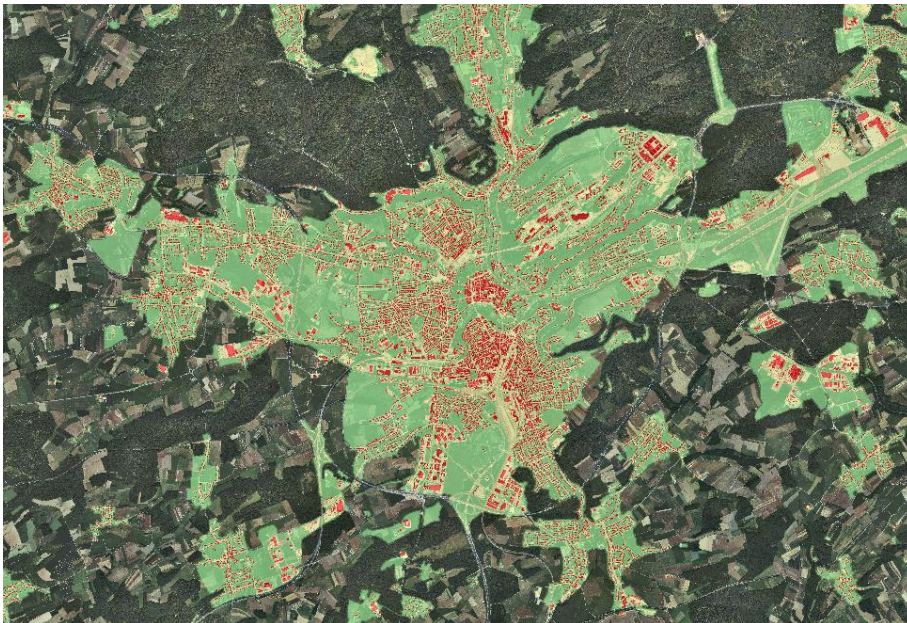


# DIGITAL LAND USE MAP FROM ORTHOPHOTOS IN LUXEMBOURG

- Deliverable 1b + 1c: Status 2004 and 2001 -

## Final Technical Report



Reporting:

Dipl.-Geogr. Florian Jäger, *GeoVille Informationssysteme*  
[Mag. Wolfgang Stemberger, GeoVille Informationssysteme](#)  
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GeoVille Information ~~S~~ssysteme und  
[Datenverarbeitung GmbH GmbH](#)  
Sparkassenplatz 2, 3rd floor  
A-6020 Innsbruck

Tel.: ++43-(0)512-562021-0  
Fax: ++43-(0)512-562021-22  
E-Mail: [info@geoville.com](mailto:info@geoville.com)  
URL: <http://www.geoville.com>

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## 1. General overview of the project

This report describes the first deliverable of the Digital Landuse Map for Luxembourg. In the first part, the orthophotos of the year 2007 were automatically classified and mapped with further preprocessing steps. Deliverable 1a was sent on October 9<sup>th</sup>.

The final report with detailed technical descriptions of the whole project will be attached to the deliverables 1b and 1c (digital land use maps 2004 and 2001).

For all products (2001, 2004 and 2007) ~~three status maps~~, the same ~~interpretation~~ area consisting of 390 km<sup>2</sup> was ~~mapped~~ mapped. The scale for viewing is 1:5.000.

### Project Schedule:

- Completed input datasets (orthophotos, ancillary datasets & final definition of AOI): **July, 6<sup>th</sup> 2009**
- First interim report: **September, 21<sup>st</sup> 2009**
- Deliverable 1a and short technical report: **October, 9<sup>th</sup> 2009**
- Deliverable 1b and 1c, final technical report: **November, 16<sup>th</sup> 2009**

### Input data sets:

- [Digital RGB-orthophotos of the years 2007, 2004 and 2001 \(resolution 50 cm\)](#)
- [Digital colour infrared-orthophotos of the year 2007 \(resolution 50 cm\)](#)
- [Settlement outlines \(„perimetre 2004“ and „perimetre 2007“\), delivered by CEPS](#)
- [Ancillary data for validation and assistance](#)
  - [Existing building layer from digital cadastre \(scale 1:5.000\) for buffering and validation](#)
  - [OBS 2000 – Layer](#)
  - [BD-L-TC \(Banque de données topo/cartographique Luxembourg\)](#)
  - [Corine Landcover Data \(CLC 2000\)](#)

### Interpretation area Area of interest (AOI):

~~Total area: 390 km<sup>2</sup>~~ The AOI had to be generated through a combination of various input data and processing steps as no predefined settlement layer exists for Luxembourg.

Urban perimeters from 2004 or, when available, and the urban classes of the OBS 2000 – Layer were merged together. Also, CLC2000 data were used as a support to complete the settlement areas.

Furthermore, the buildings from BD-L-TC were buffered to get clusters of buildings to find small settlements larger than 0.3 ha. Small, isolated buildings were not included.

Finally, the AOI was manually checked with the orthophotos of 2007 to add new buildings (and there surroundings) on the edges of settlement areas.

In the end, an AOI of 390 km<sup>2</sup> was mapped.

The interpretation area consists of the urban perimeters (delivered by CEPS)

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Mise en forme : Puces et numéros

Mis en forme : Police :Gras, Soulignement

Mis en forme : Italien (Italie)

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Mis en forme : Italien (Italie)

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Mis en forme : Police :11 pt

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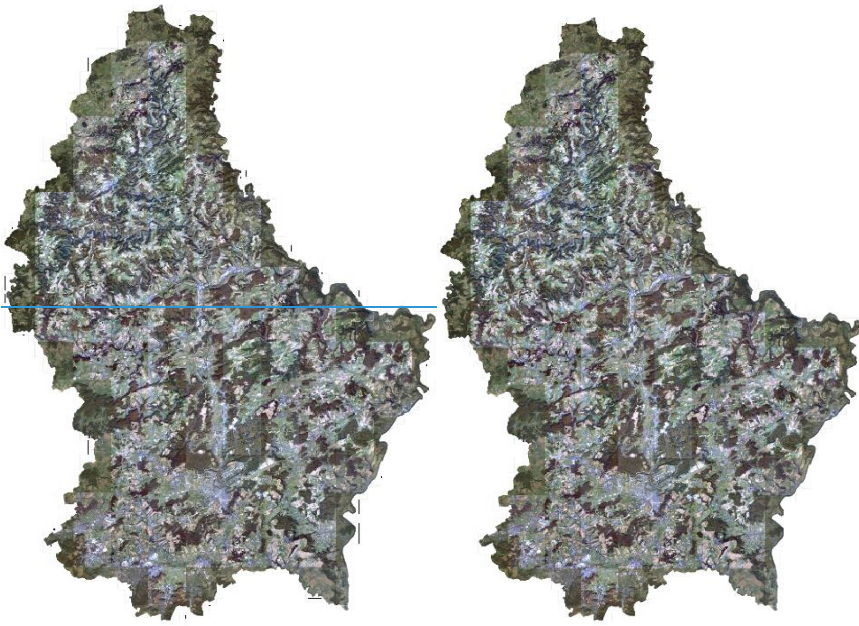
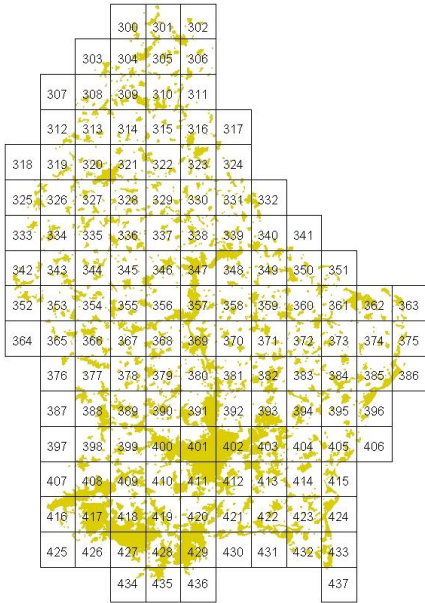


Fig.1: (left) interpretation area of Luxembourg in yellow, the cells define the working units; (right) Luxembourg in RGB-orthophoto mosaics of 2007

Mis en forme : Police :11 pt

Mis en forme : Retrait : Gauche : 1.25"

### Input data sets:

- Digital RGB orthophotos of the years 2007, 2004 and 2001 (resolution 50 cm)
- Digital colour infrared orthophotos of the year 2007 (resolution 50 cm)
- Settlement outlines („perimetre 2004“ and „perimetre 2007“)
- Ancillary data for validation and assistance
  - Existing building layer from digital cadastre (scale 1:5.000) for buffering and validation
  - OBS 2000 Layer
  - BD L TC (Banque de données topo/cartographique Luxembourg)

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### Structure of the working units

The procedure of preparing the image data sets was identical for all three years: The squarish 1 km orthofotos (for 2007 and 2004 as TIFF, for 2001 as compressed ECW-Format) were assembled to squarish mosaics of 5 km, which is a suitable size for both automatic classification and post-processing. The working units 364, 387 and 397 had image information, but had no share of the area of interest. Finally, the results for 135 working units are part of this delivery.

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## 2. Mapping Procedure

### Deliverables 1a, 1b + 1c:

All three deliverables have the same technical specifications as mentioned in the report for deliverable 1. Buildings and other artificial surfaces will be classified according to the following technical specifications:

- Artificial surfaces
  - o 1.1. Buildings (>25 m<sup>2</sup>)
  - o 1.2. Other artificial surfaces (>100 m<sup>2</sup>)
- Non-artificial surfaces (>100 m<sup>2</sup>)

Linear elements (mainly roads) were mapped if wider than 3 m.

### Definition of thematic classes:

- 1.1. Buildings: ~~Buildings buildings~~ of all types of use with a minimum area of 25 m<sup>2</sup>. The minimum length of a building site is 5 m. Building edges smaller 5 m ~~will~~ not be considered.  
An automated smoothing of building outlines could be offered, but was not part of this contract.
- 1.2. Other artificial surfaces: ~~This class is~~ comprising asphalted roads, railways and other artificial surfaces (e.g. parking lots, construction sites, mining areas) with a minimum area of 100 m<sup>2</sup> and a minimum width of 3 m.  
Road areas are classified according to their visibility in the orthophotos. A full connectivity of roads can not be provided ~~when-if~~ roads are covered or obscured by vegetation or ~~other~~ shadows
- 2. Non-artificial surfaces: ~~those areas~~ ~~This class includes~~ all vegetated areas (e.g. gardens, meadows, pasture, forest) and other non-artificial land without vegetation (e.g. cropland, rocks, water) within the ~~mapped area~~ ~~area of interest~~.

Also the following guaranteed quality assessments were met: |

- 95% overall thematic accuracy of land use map
- 95% individual accuracy of buildings
- 90% individual accuracy of other artificial surfaces

### Preparation:

For all three years, the same area of ~~interpretation interest~~ (390 km<sup>2</sup>) was mapped.

1. An AOI (area of interest — ~~interpretation area~~) had to be defined from different datasets (see ~~data~~ ~~input list~~)
2. The orthophotos ~~were mosaicked~~ to 5 km squares ~~to in order to~~ build working units (see fig.1) for all three years (2007, 2004 and 2001) – the results will be delivered in ~~those exactly the same~~ working units (numbered consecutively from 300 to 437)
3. Development of a ruleset for the automatic classification in Definiens Developer 7.0 – therefore also the NIR-band of the 2007 images was used to provide ~~a~~ better results especially regarding the determination of vegetated and non-vegetated image objects and later classification.

### Status Map 2007:

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The 2007 land use map was generated through automatic classification with the above mentioned ruleset. Since the 135 orthophoto mosaics vary a lot in the characteristics of landscape and urban structure, the ruleset had to be calibrated and adjusted for different groups of working units.

A manual correction of these datasets had to be done for checking and enhancing the results to ensure the specified accuracy of 95 % for all three land use classes.

A set of post-processing steps (e.g. applying minimal mapping units) was conducted to finalise the datasets 2007.

As an additional delivery, each working unit was also split into the three different land use classes and distributed in a separate ESRI-shapefile.

### **Change Mapping:**

Mapping of the 2004- and 2001-imagery was conducted with a different approach. The 2007 land use map was the basis for the 2004 map. Objects which have not changed were left as in the 2007 map. “False changes” due to slanted-tilted buildings (due to different times and angles of image acquisition), vegetation cover or shadow affects were not supposed to be mapped as changes.

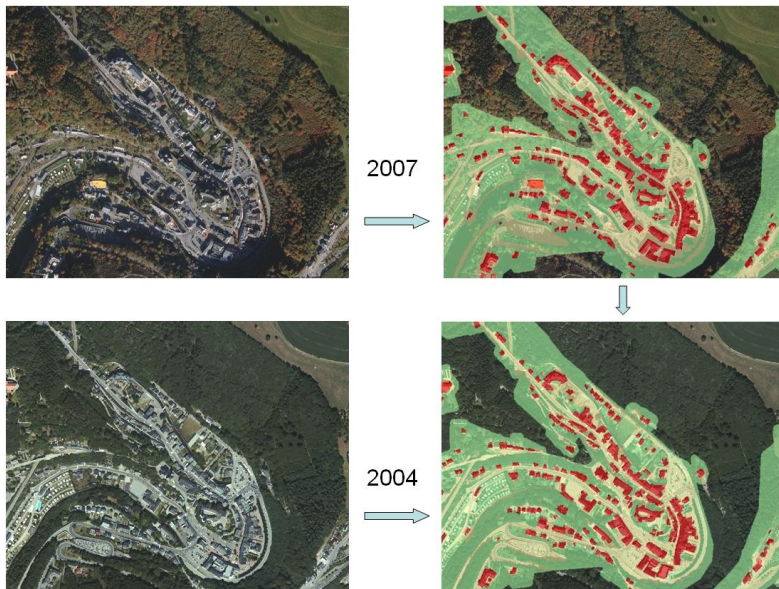


Fig. 2: Change Mapping

Changed areas were replaced by the class as interpreted in the 2004 images.

Again, the same set of post-processing steps was applied to the first change-map as in the 2007 Land Use Map.

So far, the down-date of 2001 was done by the same principles, just by using the finalised and validated 2004 land use map as basis.

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Mis en forme : Couleur de police : Automatique

Mis en forme : Couleur de police : Automatique

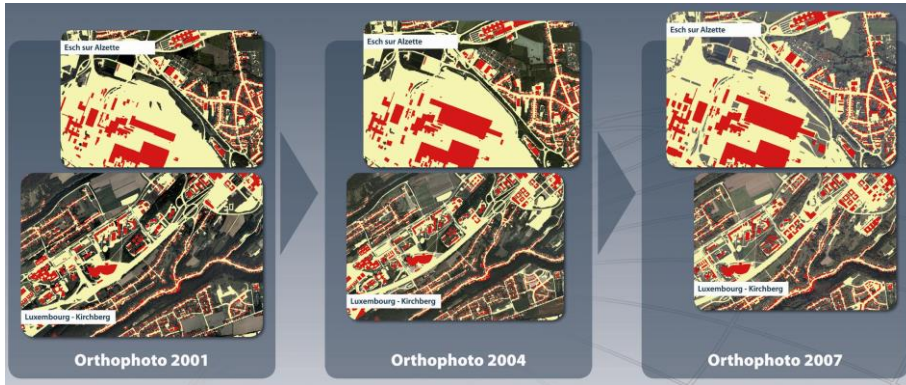


Fig. 3: Development of Land Use in two selected areas of Luxembourg (see Fig. 4)

Mis en forme : Couleur de police : Automatique



## 2.3. Description of delivery

### Deliverable 1b + 1c: Digital land use map for 2004 and 2001

- 135 ESRI-Shapefiles of the mapping results:  
<number of working unit>\_lux2004.shp
- 135 ESRI-Shapefiles of the mapping results:  
<number of working unit>\_lux2001.shp
- ESRI-Shapefiles with only one class (1.1., 1.2 or 2) for each working unit and year  
<number of working unit>\_lux\_04\_class11.shp  
<number of working unit>\_lux\_04\_class12.shp  
<number of working unit>\_lux\_04\_class2.shp

These datasets are the result of an automated land use classification in un-smoothed form. This means, the pixel structure follows the outlines of the orthophotos. All together 390 km<sup>2</sup> were mapped. The final results are delivered in the projection LUREF.

Projection: Transverse Mercator  
False Easting: 80000.000000  
False Northing: 100000.000000  
Central Meridian: 0.107629  
Scale Factor: 1.000000  
Latitude Of Origin: 0.869756  
Linear Unit: Meter (1.000000)  
Datum: LUREF

The attribute tables appear in the following structure:

- Column „ID“: unique identification number for each polygon
- Column „Gridcode“: land use code
  - o „1“ = 1.1 Buildings (>25 m<sup>2</sup>)
  - o „2“ = 1.2 Other artificial surfaces (>100 m<sup>2</sup>)
  - o „3“ = 2 Non-artificial surfaces (>100 m<sup>2</sup>)

Legend files (\*.avl, \*.lyr) were added to the deliverable mapping results.

Ancillary data:

#### Structure of the working units

Also here, the procedure of preparing the image data sets was identical for all three years. The squarish 1 km orthophotos (for 2004 as TIF, for 2001 as compressed ECW-Format) were assembled to squarish mosaics of 5 km, which is a suitable size for both automatic classification and post-processing. The working units 364, 387 and 397 had image information, but had no share of the interpretation area. In all, finally, the results for 135 working units are part of this delivery.

- Outline of the interpretation area as ESRI-Shapefile:  
(aoi\_luxembourg.shp)
- Structure of working units (5x5 km mosaics) as a ESRI-Shapefile:  
(mosaics\_5x5km.shp)

Quality assessment data sets:

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Mis en forme : Retrait : Gauche : 0.25"

Mis en forme : Couleur de police : Automatique

Mis en forme : Retrait : Première ligne : 0"

Mis en forme : Surlignage

Mis en forme : Justifié, Retrait : Première ligne : 0.49"

Mis en forme : Anglais (Royaume-Uni)

Mis en forme : Retrait : Gauche : 0", Première ligne : 0"

Mis en forme : Police : Non Italique

- Point samples as ESRI Shapefile, n=3000 points  
(*validation2004\_sample\_3000points.shp*)
  - ~~Column „ID“~~
  - ~~Column „reference“~~
  - ~~Column „map“~~
- Point samples as ESRI Shapefile, n=3000 points  
(*validation2001\_sample\_3000points.shp*)

Attribute tables:

- ~~Column „ID“~~
- ~~Column „reference“~~
- ~~Column „map“~~
- ~~Column „map“~~

Mise en forme : Puces et numéros

Mis en forme : Police :Non Italique

Mis en forme : retrait : Gauche : 0.25"

Mise en forme : Puces et numéros

Mise en forme : Puces et numéros

### 3.4. Quality control

#### Concept of validation:

The quality control is based on point samples consisting of a representative sample of 3000 points. These points are created automatically and are randomly distributed over the whole mapping area. In general, the amount of validation points depends on the number of classes and the area of each class. To emphasise the role of the buildings and the built-up area, these classes are represented much stronger in relation to the total area than the non-artificial areas.

#### Deliverable 1a) Results of the point-based quality control (3000 points) for the 2007 land use map:

##### Confusion matrix:

		Visual reference interpretation			
		1.1	1.2	2	sum
Land use map	1.1	762	23	15	800
	1.2	27	945	28	1000
	2	37	12	1151	1200
	sum	801	1005	1194	3000

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Mis en forme : Couleur de police : Rouge

Mis en forme : Couleur de police : Automatique

##### Accuracy statistics:

Producer accuracy, user accuracy, overall accuracy for each class:<sup>1</sup>

	Producer accuracy (with 95%-confidence intervall)	user accuracy (with 95%-confidence intervall)	overall accuracy for each class
1.1 Buildings	95,13 % 93,47 – 96,79	95,25 % 94,49 – 96,01	95,19 %
1.2 Other artificial surfaces	94,03 % 92,58 – 95,48	94,50 % 93,68 – 95,32	94,26 %
2 Non-artificial surfaces	96,40 % 95,50 – 97,30	95,92 % 95,21 – 96,62	96,16 %

Overall accuracy of the land use map: **95,27 %**  
 Overall accuracy of the class „1.1 Buildings“: **95,19 %**

<sup>1</sup> Definitions of accuracies:

- User accuracy (in %): How many % of the objects in the land use map were mapped correctly?
- Producer accuracy (in %): How many % of all real objects were registered correctly in the land use map?
- Overall accuracy for each class (in %): Mean of producer and user accuracy

**Deliverable 1b) Results of the point-based quality control (3000 points) for the 2004 land use map:**

Mis en forme : Couleur de police : Automatique

**Confusion matrix:**

		Visual reference interpretation			
		1.1	1.2	2	sum
Land use map	1.1	750	34	16	800
	1.2	10	977	13	1000
	2	8	62	1130	1200
	sum	768	1073	1159	3000

**Accuracy statistics:**

Producer accuracy, user accuracy, overall accuracy for each class:<sup>2</sup>

	Producer accuracy (with 95%-confidence interval)	user accuracy (with 95%-confidence interval)	overall accuracy for each class
1.1 Buildings	93,75 % 92,88 – 94,62	97,66 % 96,52 – 98,79	95,70 %
1.2 Other artificial surfaces	97,70 % 97,16 – 98,24	91,05 % 89,18 – 92,93	94,38 %
2 Non-artificial surfaces	94,17 % 93,33 – 95,01	97,50 % 96,78 – 98,21	95,83 %

Overall accuracy of the land use map: **95,23 %**  
Overall accuracy of the class „1.1 Buildings“: **95,70 %**

**Deliverable 1c) Results of the point-based quality control (3000 points) for the 2001 land use map:**

Mis en forme : Couleur de police : Automatique

**Confusion matrix:**

		Visual reference interpretation			
		1.1	1.2	2	sum
Land use map	1.1	755	25	20	800
	1.2	12	973	15	1000
	2	3	36	1161	1200
	sum	770	1034	1196	3000

**Accuracy statistics:**

Producer accuracy, user accuracy, overall accuracy for each class:<sup>3</sup>

<sup>2</sup> Definitions of accuracies:

- User accuracy (in %): How many % of the objects in the land use map were mapped correctly?
- Producer accuracy (in %): How many % of all real objects were registered correctly in the land use map?
- Overall accuracy for each class (in %): Mean of producer and user accuracy

<sup>3</sup> Definitions of accuracies:

- User accuracy (in %): How many % of the objects in the land use map were mapped correctly?
- Producer accuracy (in %): How many % of all real objects were registered correctly in the land use map?
- Overall accuracy for each class (in %): Mean of producer and user accuracy

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 Digital Land Use Map from Orthophotos – Deliverables 1b+1c (2004+2001)

	Producer accuracy <i>(with 95%-confidence interval)</i>	User accuracy <i>(with 95%-confidence interval)</i>	Overall accuracy for each class
1.1 Buildings	94,38 % 93,55 – 95,20	98,05 % 97,03 – 99,07	<b>96,21 %</b>
1.2 Other artificial surfaces	97,30 % 96,72 – 97,88	94,10 % 92,61 – 95,59	<b>95,70 %</b>
2 Non-artificial surfaces	96,75 % 96,12 – 97,38	97,07 % 96,28 – 97,87	<b>96,91 %</b>

Overall accuracy of the land use map: **96,30 %**  
 Overall accuracy of the class „1.1 Buildings“: **96,21 %**

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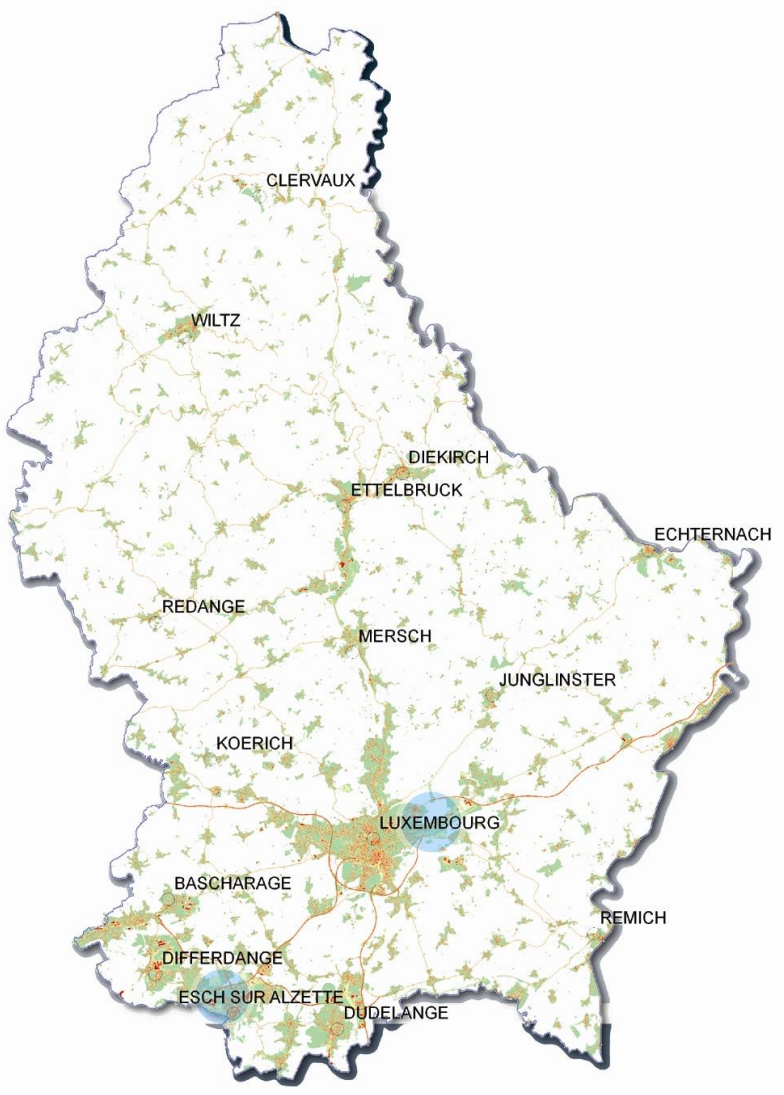


Fig. 4: Land use map of Luxembourg, 2007 (mapped from orthophotos)