

→ MAPPING URBAN AREAS FROM SPACE CONFERENCE

Production and validation of the European Urban Atlas for 2006 and 2012

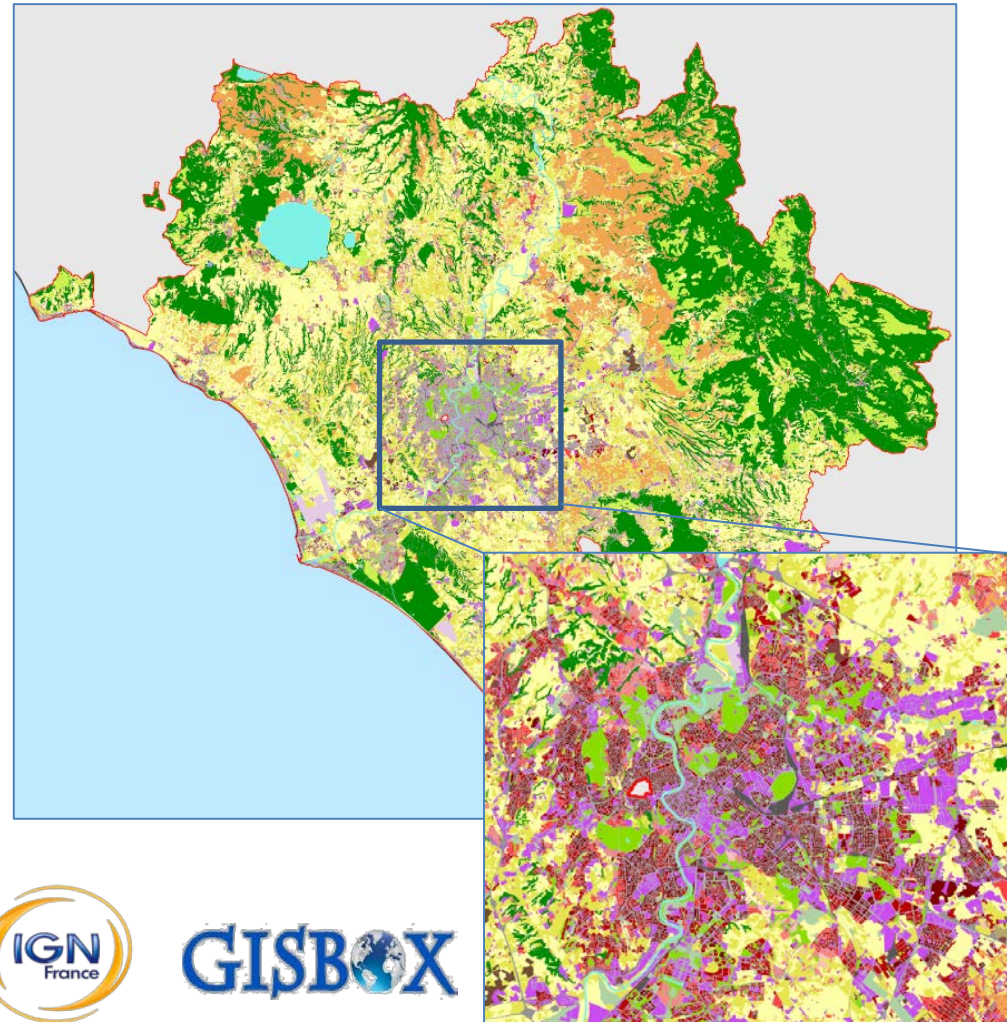
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What is the Urban Atlas?



- First implementation of the Local Component of the Copernicus Land Monitoring Service with the Urban Atlas 2006 and now 2012 update and extension
- EC DG Regio led initiative to complement the Urban Audit
- Provides **harmonised Land Use /Land Cover maps** according to a common classification across Europe
- Urban Planning Tool to:
 - Monitor effects (positive or negative) of structural investment decisions
 - Compare between cities based on a common language
 - Monitor Urban sprawl more accurately



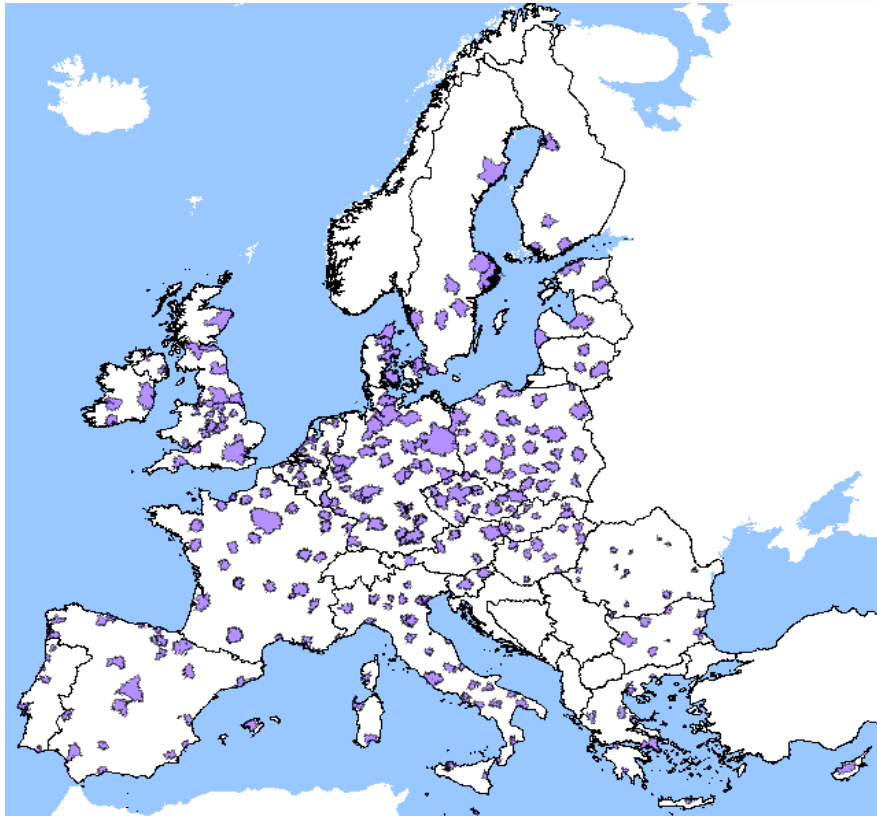
UA2006 versus UA2012



Urban Atlas 2006	Urban Atlas 2012
305 UA 2006 Functional Urban Areas (FUA), formerly Large Urban Zones (LUZ)	697 UA 2012 FUAs including 301 existing UA2006 FUAs and 396 new FUAs
Most EU27 cities over 100,000 inhabitants	Most EU28 cities over 50,000 inhabitants
17 Urban classes with 0.25ha MMU	17 urban classes with MMU 0.25 ha; minor nomenclature changes
3 Rural Classes with MMU 1ha	10 Rural Classes with MMU 1ha
No street tree layer	Street tree layer

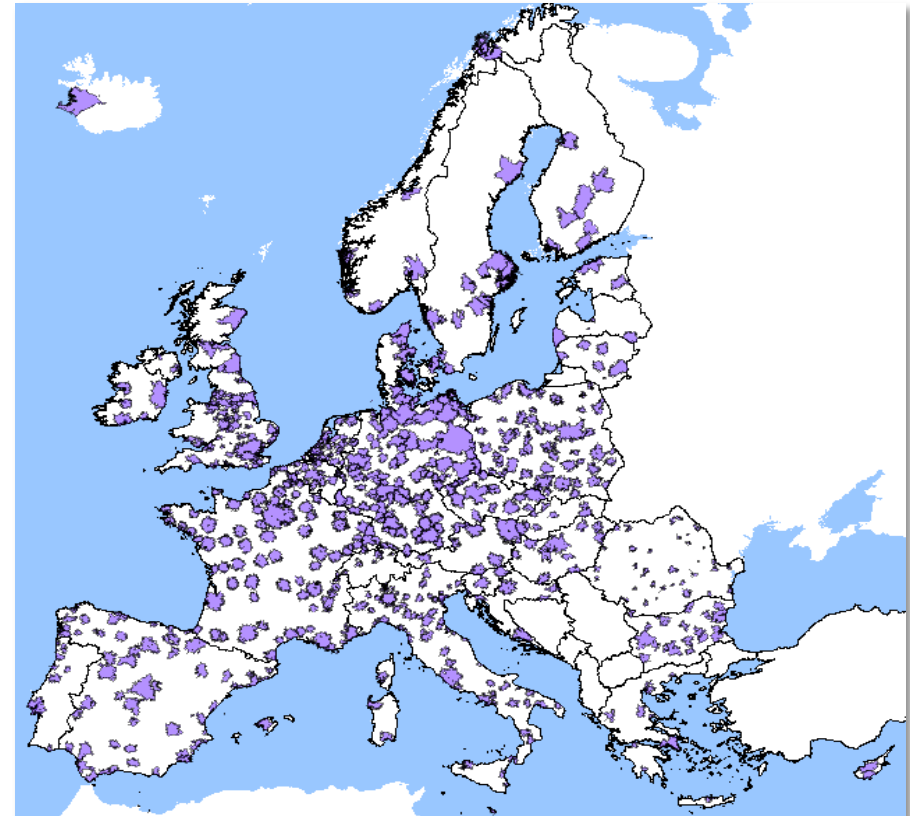
Evolution of FUAs in Urban Atlas

UA2006



~600,000 km²

UA2012



~1,000,000 km²

-  Continuous Urban fabric
-  Discontinuous Dense Urban Fabric
-  Discontinuous Medium Density Urban Fabric
-  Discontinuous Low Density Urban Fabric
-  Discontinuous Very Low Density Urban Fabric
-  Isolated Structures
-  Industrial, commercial, public, military and private units
-  Fast transit roads and associated land
-  Other roads and associated land
-  Railways and associated land
-  Port areas
-  Airports
-  Mineral extraction and dump sites
-  Construction sites
-  Land without current use
-  Green urban areas
-  Sports and leisure facilities
-  Agricultural Areas, semi-natural areas and wetlands
-  Forests
-  Water
-  No data



To be based on local average soil sealing

Urban Atlas 2012 Nomenclature



-  Arable land annual crops
-  Permanent crops
-  Pastures
-  Complex and mixed cultivation patterns
-  Orchards
-  Herbaceous vegetation associations
-  Open spaces with little or no vegetation
-  Wetlands

Automatic Change Detection of Built-up areas



Heerlen (NL) 2006 Image



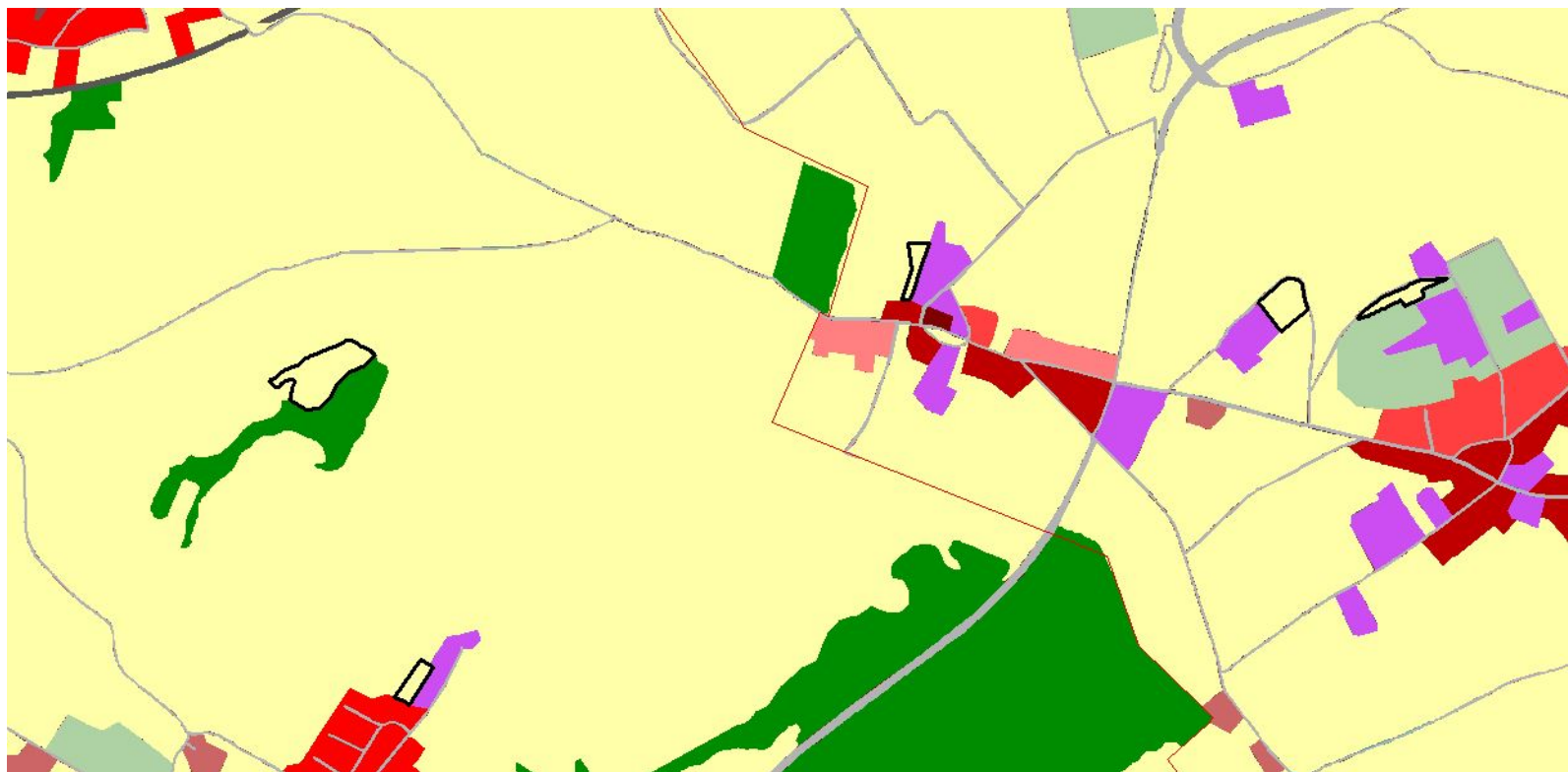
Changes Detected

Heerlen (NL) 2012 Image



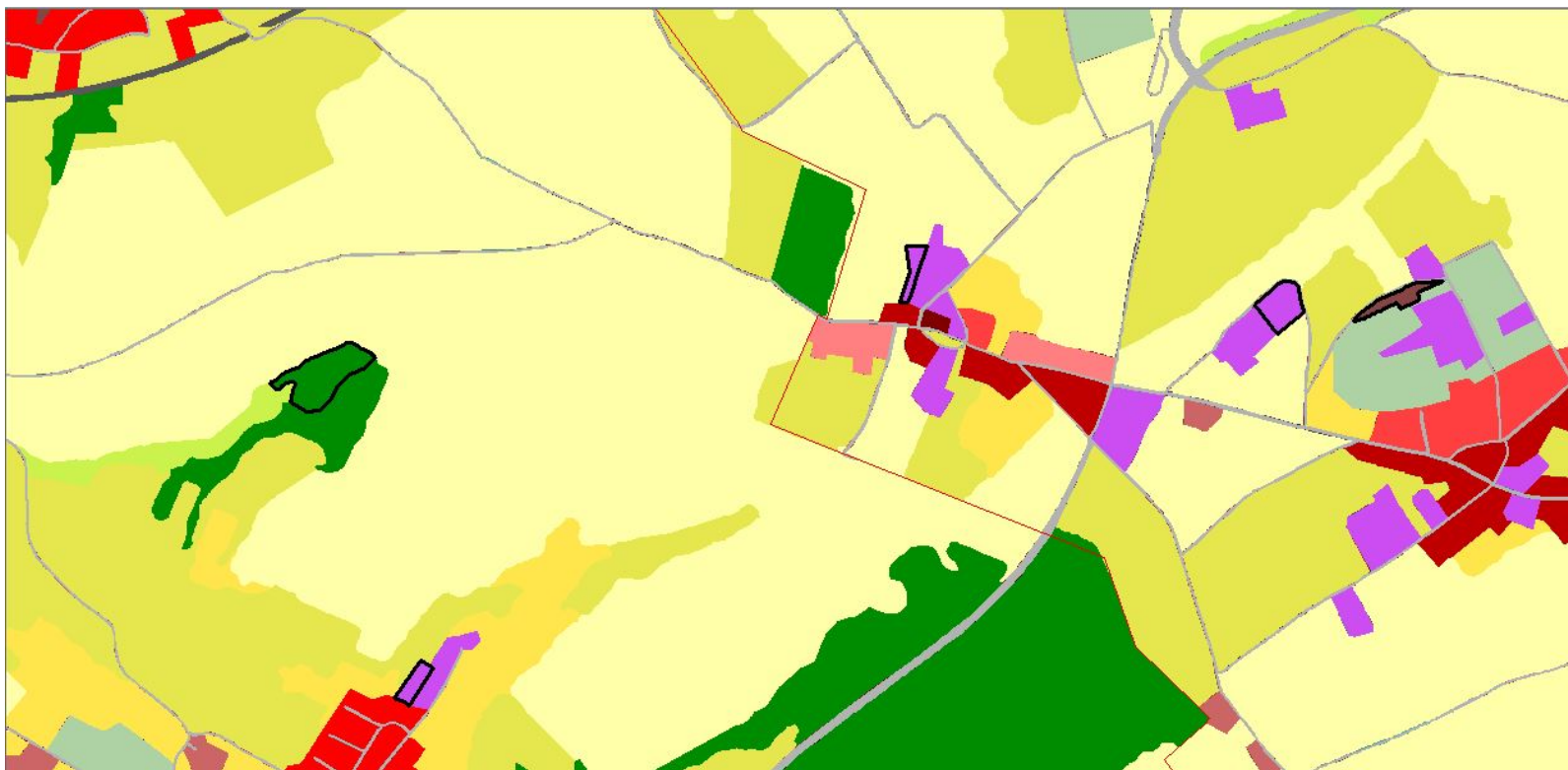
 Changes Detected

Heerlen (NL) UA 2006



 Changes Detected

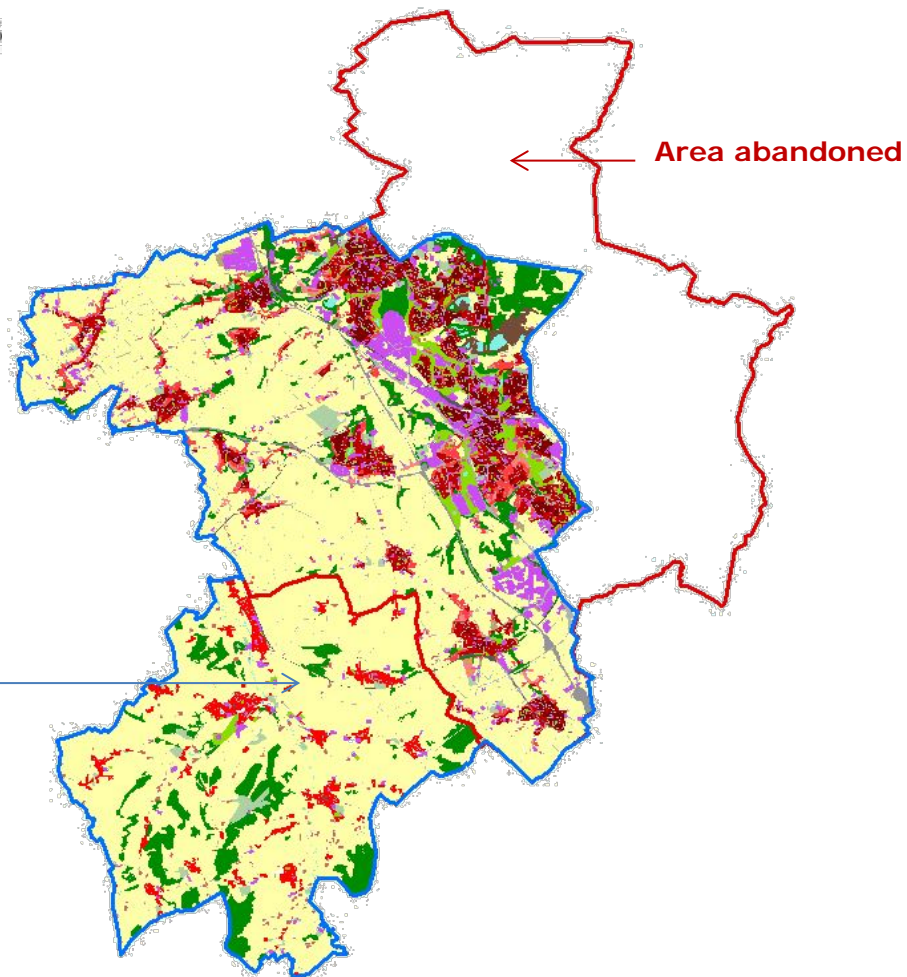
Heerlen (NL) UA 2012



Changes Detected

Heerlen (NL) UA 2012 overview

- 11100: Continuous Urban fabric (S.L. > 80%)
- 11210: Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- 11220: Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- 11230: Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- 11240: Discontinuous very low density urban fabric (S.L. < 10%)
- 11300: Isolated Structures
- 12100: Industrial, commercial, public, military and private units
- 12210: Fast transit roads and associated land
- 12220: Other roads and associated land
- 12230: Railways and associated land
- 12300: Port areas
- 12400: Airports
- 13100: Mineral extraction and dump sites
- 13300: Construction sites
- 13400: Land without current use
- 14100: Green urban areas
- 14200: Sports and leisure facilities
- 21000: Arable land (annual crops)
- 22000: Permanent crops
- 23000: Pastures
- 24000: Complex and mixed cultivation patterns
- 25000: Orchards
- 31000: Forests
- 32000: Herbaceous vegetation associations
- 33000: Open spaces with little or no vegetations
- 40000: Wetlands
- 50000: Water

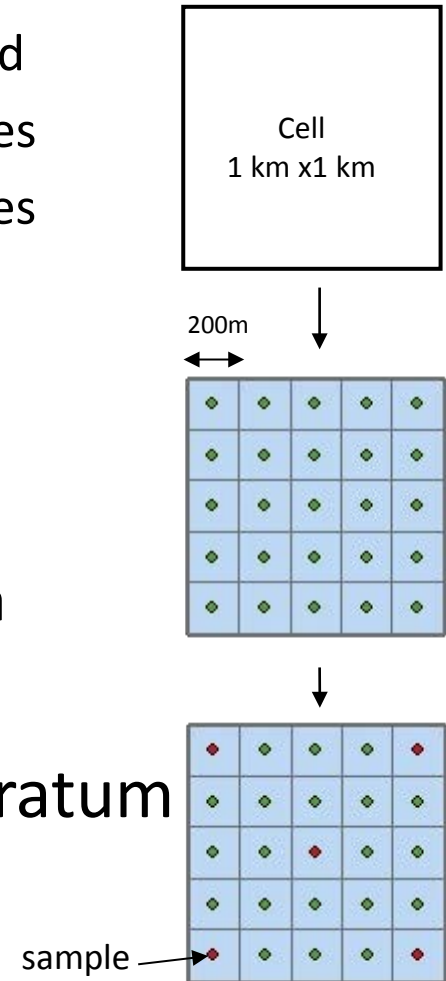


Production status

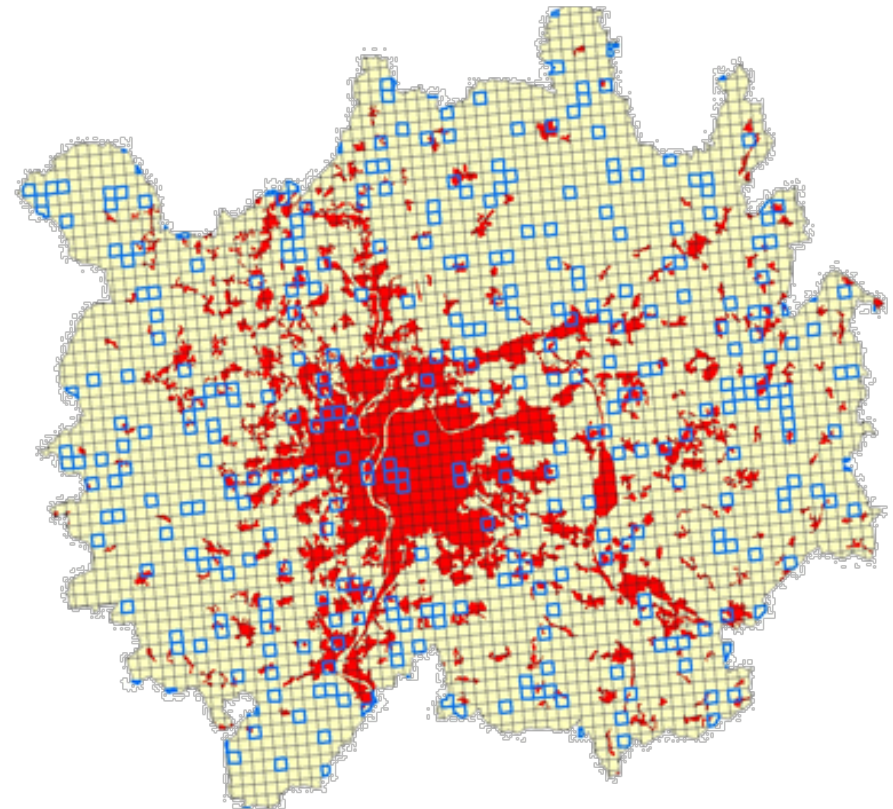


Services	Number of produced LUZs	Area Produced (km ²)	Total Area	Completion Rate (%)
Production of the revised UA2006 datasets	219	469675	640500	73%
Production of UA2006-2012 change layers	187	376920	640500	59%
Production of UA2012 existing FUAs	187	376920	640500	59%
Production of UA2012 extension to new FUAs	198	203895	375100	54%
TOTAL UA2012 (Existing & New FUAs)	385	580815	1015600	57%
Production of an additional street trees layer	169	216600	1015600	21%

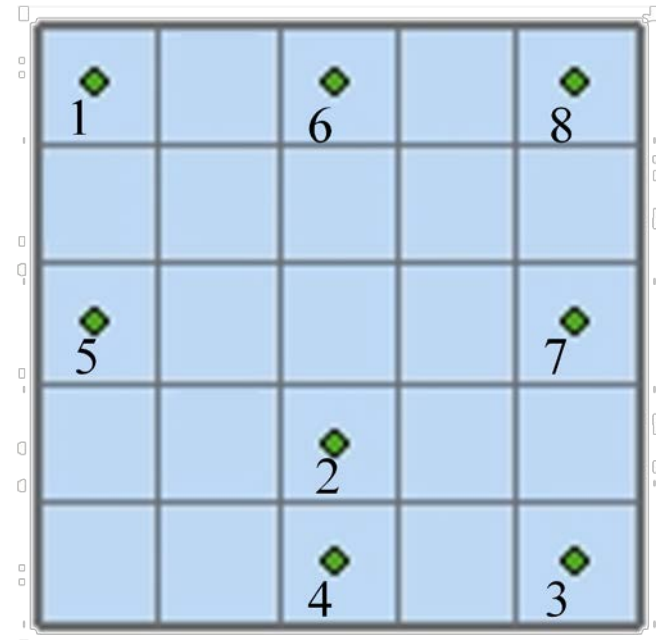
- Target accuracy:
 - HRL IMD derived sub classes are not to be validated
 - **85%** accuracy for **urban** level 3 + rural level 1 classes
 - **80%** accuracy for **rural** level 2 + urban level 1 classes
- Stratified random sampling
- Two stage sampling design:
 - EEA 1km grid LAEA ETRS89 projection
 - CLC2006 to determine urban vs rural strata
 - 200m grid within selected 1km grid cell
- Target: 65% of sample units in Urban stratum
- Full double blind approach



- Intersection of CLC2006 and EEA LAEA 1km grid
- Random selection of 1km grid cells for each stratum
- On average 7% in rural areas and 10% in urban areas
- Sampling fractions can be adjusted depending on proportion of rural/urban in LUZs

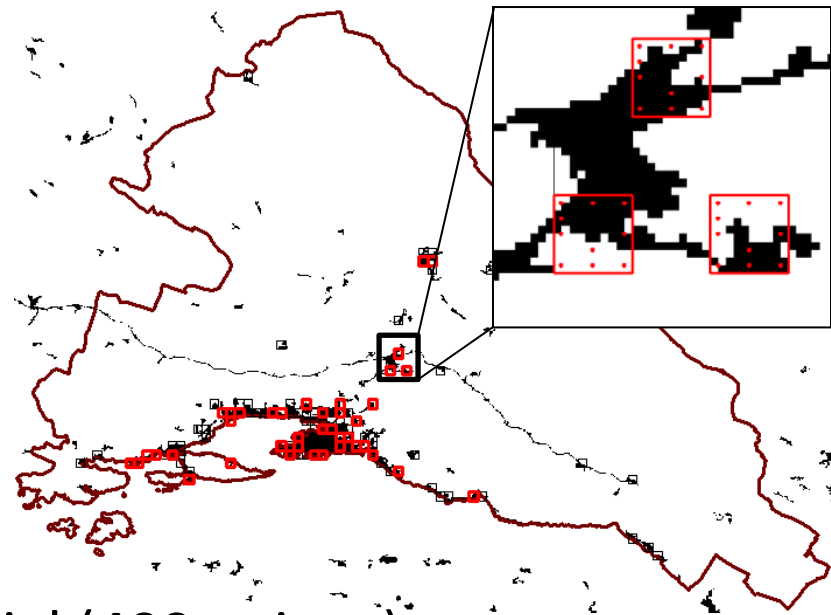


- Based on a 200 m grid
- Population represented by grid centroid
- Each centroid is a potential replicate within sampled 1km cell
- Total of 25 potential replicates number of replicates adjusted to comply with 65/35 ratio
- For an average case this would be 1 replicate for rural and 8 for urban:

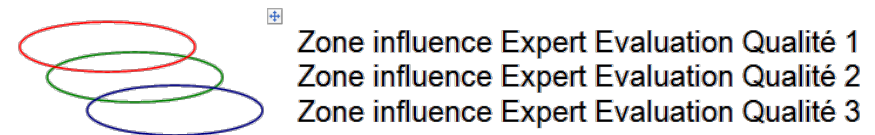


Split (HR) FUA Example

- Target 1 SSU/ 5 km²:
622 SSUs in total
- 65% SSUs in artificial areas
and 35% in rural areas
- This can be achieved with:
 - 40 PSUs (39% sampling rate)
and 10 SSU replicates for artificial (400 points)
 - 220 PSUs (7.3% sampling rate) and 1 SSU replicate for rural
areas (220 points)
- Resulting in 64.5% of points in artificial stratum and
35.5% in rural stratum



- Double blind approach:
 - Production not aware of SSU location
 - UA 2012 products not provided to QC Experts
- Visual Interpretation of UA 2012 imagery and available ancillary data
- Three experienced experts covering the diversity of EU conditions



External Validation

- EEA Framework service contract for the validation of Copernicus local and pan-European Land monitoring service
- Fully independent process
- Same target accuracy to that of internal QC
- Stratified Systematic sampling approach based on LUCAS sampling frame
- First level stratification based on FUA types according to area: small (<math><1,500 \text{ km}^2</math>), medium (>math>>1,500\text{km}^2</math> & <math><5,000\text{km}^2</math>) and large (>math>>5,000 \text{ km}^2</math>)
- Second level stratification based UA2012 LCLU layer to ensure full representation of UA2012 thematic classes
- ~ 51,000 sample units processed so far corresponding to 45 % of FUAs



European Environment Agency



Sample design

- Stratified systematic sample design based on LUCAS 2 x 2 km sampling frame
- Sub sampling of LUCAS grid at 200 x 200 m for very small strata
- Selection of Sample Units based on LUCAS and densified LUCAS grid
- Sample unit is a point located within production polygon to avoid errors associated with geometry

18km

9	23	66	44	68	10	48	16	42	76	23	66	44	68	10	48	16	42	76
8	71	12	69	25	51	29	60	37	7	71	12	69	25	51	29	60	37	7
7	20	79	18	72	78	3	31	63	70	20	79	18	72	78	3	31	63	70
6	33	1	80	11	59	32	38	9	64	33	1	80	11	59	32	38	9	64
5	28	40	26	49	55	17	53	50	77	28	40	26	49	55	17	53	50	77
4	45	27	41	67	6	65	15	73	5	45	27	41	67	6	65	15	73	5
3	35	39	13	36	62	21	57	24	47	35	39	13	36	62	21	57	24	47
2	8	58	74	46	14	75	2	56	34	8	58	74	46	14	75	2	56	34
1	43	30	4	54	61	19	81	22	52	43	30	4	54	61	19	81	22	52
9	23	66	44	68	10	48	16	42	76	23	66	44	68	10	48	16	42	76
8	71	12	69	25	51	29	60	37	7	71	12	69	25	51	29	60	37	7
7	20	79	18	72	78	3	31	63	70	20	79	18	72	78	3	31	63	70
6	33	1	80	11	59	32	38	9	64	33	1	80	11	59	32	38	9	64
5	28	40	26	49	55	17	53	50	77	28	40	26	49	55	17	53	50	77
4	45	27	41	67	6	65	15	73	5	45	27	41	67	6	65	15	73	5
3	35	39	13	36	62	21	57	24	47	35	39	13	36	62	21	57	24	47
2	8	58	74	46	14	75	2	56	34	8	58	74	46	14	75	2	56	34
1	43	30	4	54	61	19	81	22	52	43	30	4	54	61	19	81	22	52

Row in block

Column in block →

- Ensure sufficient level of precision at reporting level
- Allows comparison with HRL verification results at least for countries/group of countries > 90,000km²
- Allows for analysis at main country level, but also for biogeographical regions
- Considers the number of thematic classes

$$n_h = \frac{p_h(1 - p_h)}{\sigma_h^2}$$

Where n_h is the sample size for stratum h , p_h is the expected error rate and σ_h is the desired standard error

In practice, minimum of 20-50 sample units per stratum

Interpretation of sample units based on higher resolution imagery

1. Semi-blind interpretation:

- Density: interpretation of SSUs
- Thematic: based on available image data and production polygons (not including thematic information)

Validation data can also suffer from substantial error

2. Plausibility analysis:

- Validation results are compared with map layer
- Map layer value are accepted if considered plausible
- Takes into account differences in input image data and uncertainty in class discriminability

Analysis of results

- Sampling primarily based on stratified systematic sampling
- Unequal sampling intensity between strata
- Need to correct before producing error matrices:

$$\hat{p}_{ij} = \left(\frac{1}{N}\right) \sum_{x \in (i,j)} \frac{1}{\pi_{uh}^*}$$

Total number of pixels

Sampling intensity

- To combine sample data from several strata, a weighted factor is required to account for different inclusion probabilities (Selkowitz & Stehman 2011):

- Based on ~51,000 sample units corresponding to 45% of FUAs
- **Urban** level 3 + rural level 1 classes:
 - Blind interpretation: **97.2%** overall accuracy
 - Plausibility analysis: **98.5%** overall accuracy
- **Rural** level 2 + urban level 1 classes:
 - Blind interpretation: **78.4%** overall accuracy
 - Plausibility analysis: **91.7%** overall accuracy

Large difference between blind and plausibility results for rural areas is linked to single date imagery leading to difficulty to identify arable vs pasture

Comparison of internal QC vs External validation for Paris FUA



- Total of 2,464 sample units for internal QC
- Total of 1,892 sample units for External validation
- **Urban** level 3 + rural level 1 classes:
 - Internal QC: 90.5% overall accuracy
 - External validation: 84.5% overall accuracy
- **Rural** level 2 + urban level 1 classes:
 - Internal QC: 86.1% overall accuracy
 - External validation: 89.3% overall accuracy

Conclusions



- UA 2006 has already demonstrated to be a very valuable dataset (2nd most downloaded dataset after CLC2006 from EEA website)
- Availability of UA 2012 and change layer will provide a very powerful tool to monitor urban sprawl and urban planning policies across Europe
- UA 2006 data freely available for visualisation and download from: <http://land.copernicus.eu/local/urban-atlas>
- UA 2012 data to be made available when first external validation exercise is completed (end 2015)
- Preliminary results show that UA2012 is fully compliant with thematic accuracy requirements
- Image availability remains an issue, primarily for characterizing rural areas and street tree layer production
- UA2012 production due to complete in 2016