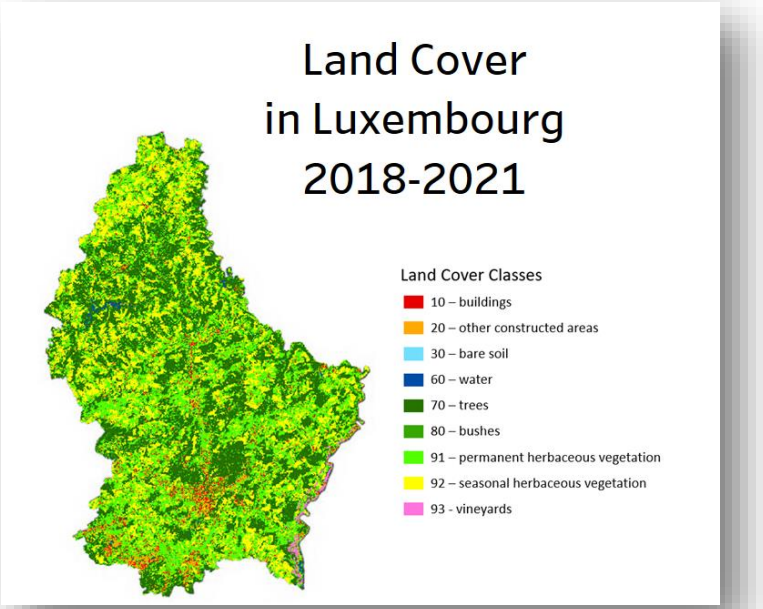
High-resolution Land Cover Map 2021

Land Cover Classification 2021 Luxembourg - using high resolution multispectral aerial imagery



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space 4 environment

«Using Space to provide Space for the Environment»

DOCUMENT RELEASE SHEET

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LIST OF ACRONYMS

LC	Land Cover
LU	Land Use
LiDAR	Light Detection and Ranging
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
OBIA	Object-Based Image Analysis

1 INTRODUCTION

Land cover (LC) and land cover change (LCC) classification is the process of mapping LC and LCC over time by analysing aerial images. It provides a comprehensive understanding of the current and past LC of an area and helps to inform decision-making and management of natural resources. By understanding the LC of an area, the classification can be used to identify areas of, e.g., deforestation, urban expansion, and other changes in LC, as well as identify potential areas of restoration and conservation. It can also enable land managers to develop strategies to mitigate the impacts of LCC on the environment. Mapping LC and its changes is an important tool for being able to respond to them appropriately. It helps to get an overview of where changes occur and how big these LCC are. The translation of aerial images into defined LC classes is an important step for this, such that they can be directly translated into area statistics and thus into indicators.

This report explains the technical approach and presents the results in comparison with the previous land cover mapping from 2018.

The technique, which was used to produce the land cover map, was an Object-Based Image Analysis (OBIA) using the software eCognition. The OBIA is an effective method of analysing high spatial resolution images to produce LC maps. This technique is an alternative to pixel-based methods which do not consider neighbouring pixels. OBIA makes use of both spectral and spatial information and groups several pixels into shapes which provide meaningful representations of objects such as buildings or trees, making it ideal for LC classification.

The result of the analysis in eCognition was a vector data set with changes between 2018 and 2021. These changes were checked again manually and then combined with the LC2018 data set. The result was a new LC2021 data set with a 2018-2021 change dataset.

2 USED DATASETS

The main dataset for the 2021 mapping was the infrared aerial image with a resolution of 0.1m (https://data.public.lu/fr/datasets/orthophoto-officielle-du-grand-duche-de-luxembourg-edition-2021/).

Compared to the Land Cover 2018 classification, we were not able to use a LIDAR dataset this time. All other data sets used are the same as those used in 2018, as listed in the following Table 2-1.

Table 2-1: Technical characteristics of input data used for classification.

INPUT DATASETS			
Name	**Type**	**Spatial resolution**	**Source**
Land Cover classification 2018	Vector	-	https://data.public.lu/en/datasets/corine-land-cover-2018/#resources
Newly Digitized Buildings	Vector	-	space4environment
FLIK data (Référentiel des parcelles agricoles FLIK – 2021)	Vector	-	https://data.public.lu/en/datasets/referentiel-des-parcelles-flik/#resources
Orthophoto 2021 (red, green, blue and NIR bands)	Raster	0.1m	https://data.public.lu/en/datasets/orthophoto-officielle-du-grand-duche-de-luxembourg-edition-2021/
NDVI (derived from red and NIR bands)	Raster	0.1m	space4environment
Brightness (derived from NIR, red and green bands)	Raster	0.1m	space4environment
NDVI 2018 (from orthophoto)	Raster	0.2m	https://data.public.lu/fr/datasets/orthophoto-officielle-du-grand-duche-de-luxembourg-edition-2018/#resources
NDVI Sentinel image time series (April – October 2021)	Raster	10m	EO- Browser https://apps.sentinel-hub.com/eo-browser/

For both the orthophoto 2021 & 2018 and the single Sentinel images the normalised difference vegetation index (NDVI) was calculated. From these individual images, an NDVI time series was created, which is used for the subsequent classification. To optimise the building class (10), a manual attempt was made in advance to revise the existing building dataset from 2018 and then take it as input for the segmentation. This had the advantage that the building objects could be mapped clearly, i.e., if buildings were partially obscured by shadows or trees, the full footprint of the building could still be captured by the manual step. The brightness raster dataset was created within the software eCognition to obtain clear object boundaries for segmentation.

3 METHODOLOGY

To be consistent with the classification for 2018, the same terminology and number of classes were used:

- (10) Buildings
- (20) Other constructed areas
- (30) Bare soil
- (60) Water
- (70) Trees
- (80) Bushes
- (91) Permanent herbaceous vegetation
- (92) Seasonal herbaceous vegetation
- (93) Vineyards

For a detailed description of the land cover classes, please see ANNEX I.

The classification was performed in the eCognition software (version 10) which applies the OBIA approach. The flowchart in Figure 3-1 shows the main steps of the classification approach.

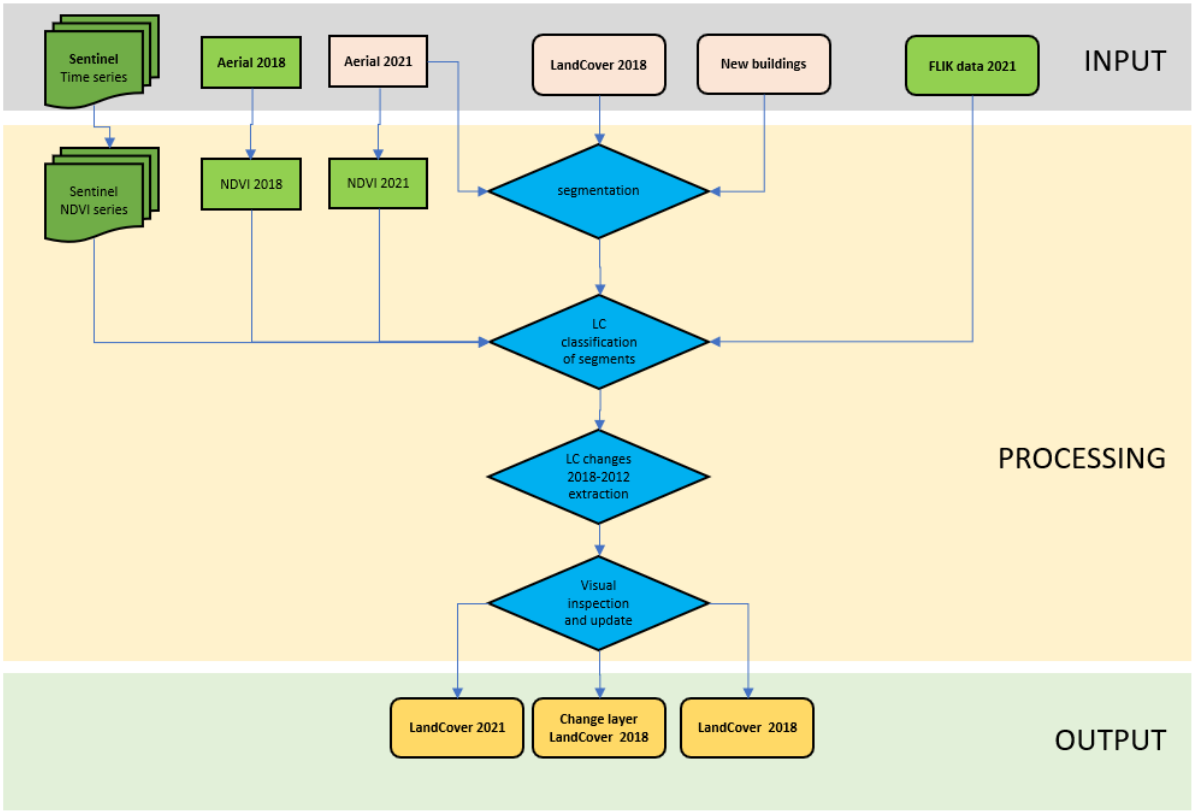

Figure 3-1: Detailed workflow of the LC 2021 classification

As mentioned, the classification was performed in eCognition where processing of large datasets takes

place in smaller parts, otherwise known as tiles. All the datasets listed in Table 2-1 were imported into the eCognition software.

3.1 SEGMENTATION

To segment the pixels of the input data into objects, a multiresolution segmentation took place. For this segmentation the following input datasets were used:

- Aerial image 2021;
- LandCover2018; and
- the updated building footprint vector dataset.

The algorithm parameters within eCognition were set at level 20, the shape of segments at 0.3 and the compactness to 0.5. These parameters were chosen after performing several tests and subsequent visual verification of the outputs.

3.2 CLASSIFICATION

After the segmentation a classification in eCognition started using all datasets listed in Table 2-1. For each segment, it was first checked whether it still corresponded to the land cover recorded in 2018 or deviated from it. For this purpose, all available data information was queried. If, for example, a segment that was mapped as a tree in 2018 now has a very low NDVI (i.e., lack of vegetation), this segment was initially mapped as possible change. In further steps, this statement was further examined and if it was proven to be correct, this segment was recorded as a change from the class tree (class 70) to, e.g., other constructed areas (class 20).

Some of the detected changes could not be clearly classified automatically: such as a new trampoline in the garden. This was then transferred to the class that is most probable but marked for later manual checking. By using an aerial photo with the higher resolution than 2018 (20 cm → 10 cm), these cases were more numerous than previously suspected. Objects such as toys, tents, cars, parasols, animals, etc. can be clearly seen on the 2021 images and were partially recorded individually by the segmentation. Another problem was that we do not have up-to-date LIDAR data for 2021. Therefore, it became difficult to automatically distinguish between trees and bushes.

To clarify all these cases in eCognition, the processing time would have increased considerably. Therefore, it was decided to extend the manual revision and to solve the "problematic cases" there. In the last step, a vector change layer was extracted from eCognition, which contained the LC2021 and LC2018 code and handed it over to manual revision.

3.3 VISUAL INSPECTION & FINAL REFINEMENT

This preliminary change layer was then reviewed and revised by experts. Incorrect changes have been removed or corrected. If errors were discovered in the LC2018, these were marked as technical

changes (t) to be able to create a revised LC2018 later. After the entire data set was checked, it was combined with the LC2018 vector classification. The LC2018 codes were adopted as the new LC2018 and a new LC2021 data set was created from the LC2021 codes. In addition, a change layer 2018-2021 was created with the two types of changes: technical (t) and real (r) changes.

4 DISCUSSION

As previously mentioned, using a higher resolved dataset caused problems (detection of many small objects, which should not be recorded as a separate land cover class like cars, animals, ...). Another problem was that the 2018 classification segments are related to an image with 20 cm resolution. In addition, parts were manually revised in 2018 and small objects were added to neighbouring larger objects. If these segments are now "placed" on the new image and the segmentation and classification system searches for changes within these objects, they will quickly find them (e.g., other shadows cast by buildings).

It should therefore be considered whether better - more stable in terms of time - object boundaries should be defined in the future. That could be next to the road network, e.g., also the individual parcels. The following Figure 4-1 illustrates this problem. Depending on the shadows cast and the angle of view of the group of trees, the object boundary is recognised differently.

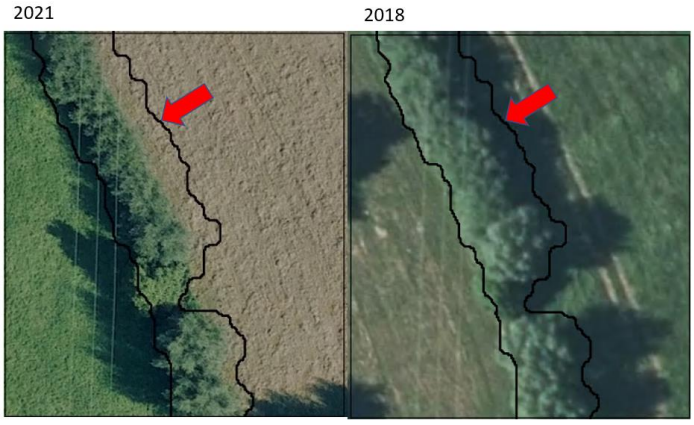

Figure 4-1 Example of non-stable object boundaries (parcel boundaries stem from LC2018)

If the parcel boundary were to be included in the segmentation as a data set, a clearer demarcation could be created (see Figure 4-2).

Figure 4-2 Example of stable object boundaries

5 RESULTS

The LC classification for 2021 of the entire Grand Duchy of Luxembourg subdivided according to communes is provided in vector and raster formats. As some small errors were also found in the LC 2018 dataset and were revised with the help of the technical changes, the version for 2018 was also rebuilt.

Finally, the following spatial datasets in LUREF projection (EPSG: 2169) were created:

1) **Land Cover 2018**

- File Geodatabase (gdb): **LC_2018.gdb**

  A polygon vector land cover classification for entire Luxembourg with the numerical LC 2018 class attribute [LC18] and commune name [COMMUNE].

- File Geodatabase (gdb): **LC_2018_commune.gdb**

  A polygon vector land cover classification for the 102 Luxembourg municipalities with the numerical LC 2018 class attribute [LC18] and commune name [COMMUNE].

- Raster (tif): **LandCover2018_raster.tif**

  An 8bit geotiff raster file with a pixel size of 0.2, 0.2 m with land cover classification codes [VALUE].

2) **Land Cover 2021**

- File Geodatabase (gdb): **LC_2021.gdb**

  A polygon vector land cover classification for entire Luxembourg with the numerical LC 2021 class attribute [LC21] and commune names [COMMUNE].

- File Geodatabase (gdb): **LC_2021_commune.gdb**

  A polygon vector land cover classification for the 102 Luxembourg municipalities with the numerical LC 2021 class attribute [LC21] and commune name [COMMUNE].

- Raster (tif): **LandCover2021_raster.tif**

  An 8bit geotiff raster file with a pixel size of 0.2m x 0.2m with land cover classification codes [VALUE].

3) Land Cover changes 2018-2021

- File Geodatabase (gdb): **LC_2018_2021_changes.gdb**

  A polygon vector land cover classification for entire Luxembourg with the numerical LC 2018 class attribute [LC18], LC 2021 class attribute [LC21], the change type [change_type] and the commune's name [COMMUNE].

  The change type code:

  - (r) real changes - correct changes between 2018 and 2021
  - (t) technical changes - changes, where errors were found in the 2018 data set. Therefore, these have been corrected and defined as technical errors.

- File Geodatabase (gdb): **LC_2018_2021_changes_commune.gdb**

  A polygon vector land cover classification for entire Luxembourg with the numerical LC 2018 class attribute [LC18], LC 2021 class attribute [LC21], the change type [change_type] and the commune's name [COMMUNE].

  The change type code:

  - (r) real changes - correct changes between 2018 and 2021
  - (t) technical changes - changes, where errors were found in the 2018 data set. Therefore, these have been corrected and defined as technical errors.

The final LC map for 2021 is depicted in Figure 5-1 and presents in 9 land cover classes.

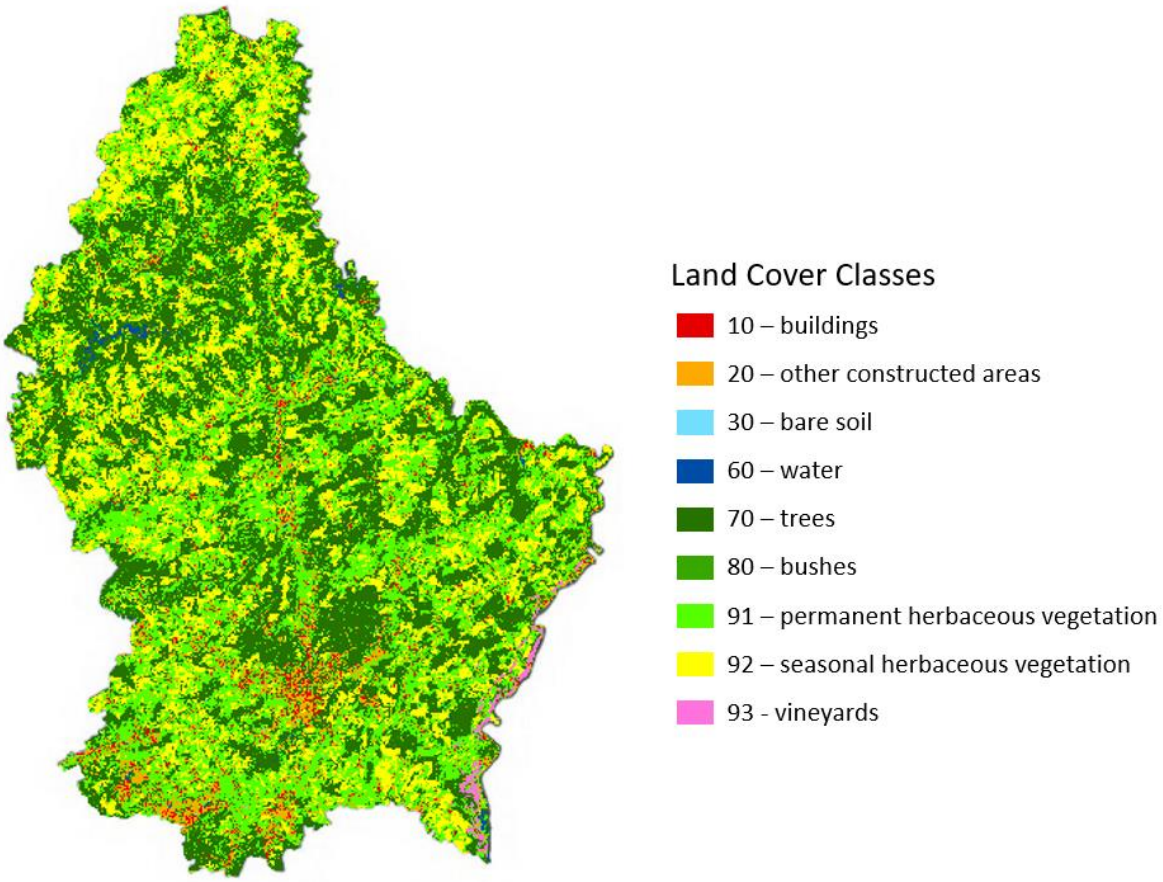

Figure 5-1: Land Cover 2021 for the Grand Duchy of Luxembourg

As can be seen in the table below the largest proportion of the country constitutes forest covering 96 439 ha of the analysed area (37.1 %). Whereas the smallest proportion corresponds to "bare soil" with only 96 ha which covers only 0.46 % of the country. Additional comparisons between 2018 and 2021 are provided in Table 5-1 below.

Table 5-1. Area covered by a particular Land Cover and the changes between 2018 - 2021 in [%] and [ha]

LC class code	2018 [ha]	Area [%]	2021 [ha]	Area [%]	Change area [ha]	Change area [% pts.]
10	4567	1.76	4770	1.84	203	0.08
20	13093	5.04	13591	5.23	498	0.19
30	133	0.05	96	0.04	-36	-0.01
60	1188	0.46	1193	0.46	4	0.00
70	97849	37.68	96439	37.14	-1410	-0.54
80	7441	2.87	7382	2.84	-59	-0.02
91	78392	30.19	79435	30.59	1042	0.40
92	55808	21.49	55569	21.40	-238	-0.09
93	1216	0.47	1213	0.47	-4	0.00
Grand Total	**259687**		**259687**			

As can be seen in the table, the proportion of sealed surface has increased. The building area has increased by 203 ha and the other sealed areas by 498 ha. On the other hand, the tree area has decreased by 1410 ha, which is due to large clear-cuts. Most of the tree areas were thereby transferred to class "Permanent herbaceous vegetation "(91).

To see how the different land over classes have changed, the following change matrix was calculated (Table 5-2):

Table 5-2 Land cover change matrix: 2018-2021

		LC2018									
AREA [ha]		**10**	**20**	**30**	**60**	**70**	**80**	**91**	**92**	**93**	**Grand Total**
LC2021	**10**	4510	142.56	2.01	0.04	14.48	12.92	81.32	6.59	0.20	4770
	20	50.18	12713	21.97	2.52	82.58	39.43	571.43	108.03	1.86	13591
	30	0.02	2.94	67	0.06	11.92	0.27	12.11	1.72	0.27	96
	60	0.32	2.68	0.08	1185	0.37	0.24	3.65	0.69		1193
	70	0.06	1.80		0.06	96431	3.68	1.74	0.05		96439
	80	0.06	1.48	0.01		19.87	7344	14.09	2.02	0.07	7382
	91	6.69	206.25	39.26	1.20	1281.83	37.99	77524	328.40	8.67	79435
	92	0.02	21.59	2.30		6.35	1.16	178.72	55359		55569
	93	0.01	0.25	0.02		0.01	1.16	4.88	1.13	1205	1213
		4567	13093	133	1188	97849	7441	78392	55808	1216	

The matrix table shows the changes in the individual land cover classes between 2018 and 2021 in [ha]. The X-axis shows the LC 2018 values and the Y-axis the LC 2021 values. The diagonal cells indicate the area that remained the same in both years. All other cells show which land cover has changed to which new land cover. For example, 1.5 km² other constructed area from 2018 became buildings in 2021.

A more detailed look at the LandCover class distribution and changes can be found at the following link to our tableau online dashboard:

https://public.tableau.com/app/profile/stefan.kleeschulte/viz/LandcoverinLuxemboug2018-2021/Story1

Figure 5-2 Tableau example and LINK

ANNEX I

Detailed description of HRLC'21 land cover classes

Land cover class code	Land cover class name
10	Buildings
20	Other constructed areas
30	Bare soil
60	Water
70	Trees
71	Dead trees
80	Bushes
91	Permanent herbaceous vegetation
92	Seasonal herbaceous vegetation
93	Vineyards

ABIOTIC (NON-VEGETATED)

The primary separation of land cover elements is based on the vegetation cover. Abiotic includes all landscape elements that are primarily not covered by vegetation. It is further differentiated whether the surface is built-up (i.e. covered by artificial material) or non-built-up and water.

Built-up surfaces

10 Buildings (Class code = 10)

Permanent construction with a roof, providing storage, shelter or residence to people, animals or things. A building is characterised by its extension into the third dimension (contrary to "other constructed area which is "flat"). A minimum height is not defined.

Parking lots with more than one floor, but without a roof are included in this class.

Buildings under construction – where the roof has not been finished – shall be classified as "other constructed areas".

Wind turbines and transformer stations are also part of the build-up class.

20 Other constructed areas (Class code = 20)

Artificial surfaces, partially or fully covered by impervious material. These artificial surfaces are usually maintained over long periods of time. Surface material includes asphalt / tarmac, concrete, gravel, or stones.

This class includes roads, sidewalks, paving's, parking lots and other artificially constructed surfaces like tennis courts, running courses, open agricultural silos, and swimming pools.

Artificial objects having extension into the three dimensions, but without a roof or that may be only temporal (e.g. tents, greenhouses) are classified into this class.

Surfaces associated to construction sites, commerce, or industry (storage areas, access roads, and mining areas) and permanent agricultural roads are included in this class.

Filled and unfilled water containers, which are sometimes found in agricultural enterprises and sewage treatment plants, are also assigned to this class.

Bare areas

30 Bare soil (Class code = 30)

Naturally open soil permanently not covered by vegetation where the maximum vegetation share is 5%. If more than 5% of bare soil is seasonally covered by natural vegetation, then the area should be classified as "herbaceous vegetation".

This class includes also artificial surfaces that are not covered by vegetation or impervious material such as: sand on golf courses, sand in playgrounds, beach volleyball courts, animal tracks, equestrian facility, areas temporary not covered by vegetation that are located close to a construction site and areas inside the construction sites that are not constructed and which the future state is not sure (bare areas between road lines on the highway, which are designed to be grassland).

Water

60 Surface water (Class code = 60)

Open surface water of running or standing water, which excludes flooded or other temporary waters. For reservoirs, the actual water level in the input EO data shall be mapped. Also, artificial objects, e.g., in the wastewater treatment plants, which are filled with water, are included in this class (this does not apply to the swimming pools or open water tanks). Lakes and ponds which are covered by solar panels are also classified as water.

BIOTIC (VEGETATED)

Biotic or vegetated surfaces represent the second main aspect of land cover classes. These surfaces are covered with biomass at the moment of the image acquisition. The amount of biomass can be detected with the help of vegetation indices (e.g., NDVI).

Woody vegetation

Perennial plants with stem(s) and branches from which buds and shoots develop. Distinction between Trees and Bushes is made based on the height information obtained from LiDAR data.

70 Trees (Class code = 70)

A tree is defined as a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown, with a height generally greater than 3m at maturity. Exceptions are young growth areas.

The class "trees" encompasses single trees, groups of trees and continuous forest stands. They normally are characterised by a height difference from their neighbouring surfaces (i.e. shadow).

Orchards, plantations and Christmas tree farms are also included under this class.

80 Bushes (Class code = 80)

Bushes are woody perennial plants with persistent woody stems and without any defined main stem in the range of 0.5 – 3m height.

Young trees with the height not exceeding 3m also belong to this class.

Herbaceous vegetation

Plants without persistent stem or shoots above ground and lacking definite firm structure.

90 Herbaceous vegetation (green cover)

Any with low vegetation covered surface (grassy or herbaceous) with an above-ground coverage of more than 5%.

9.1 Permanent herbaceous vegetation (Class code = 91)

All arable surfaces with permanent herbaceous vegetation (including intensive and extensive grasslands) fall into this class. This class contains also all vegetation-covered, but non-woody surfaces, including natural grasslands, clear cuts, pastures, parks, lawns in residential garden or green areas associated to traffic.

9.2 Seasonal herbaceous vegetation (Class code = 92)

Agricultural areas with seasonal herbaceous vegetation cover are classified into this class.

9.3 Vineyards (Class code = 93)

Agricultural areas with permanent vine vegetation cover are classified into this class.